CFTRI-MYSORE
886
Farm and garden

886

Seed germination,

" Production,

" testing,

Crops, ~~Seeds,~~ Crop seeds,

Weed seeds,

Seed act,

TLM

FARM AND GARDEN SEEDS

by

S. P. MERCER

B.Sc.(Agric.) Lond., N.D.A.

Late Professor of Agricultural Botany in
The Queen's University of Belfast
Late Head of Seed Testing and Plant Disease Division
Ministry of Agriculture, Northern Ireland

With a Section on The Seeds Act, 1920

by

A. W. MONRO, C.B.

Formerly Ministry of Agriculture and Fisheries

LONDON

CROSBY LOCKWOOD & SON LTD

39 THURLOE STREET S.W.7

1948

First published 1937
Second edition 1948

886
~~J18~~
H8
J=8
N48

CFTRI-MYSORE
886
Farm and garden

PRINTED IN GREAT BRITAIN BY RICHARD CLAY AND COMPANY, LTD.,
BUNGAY, SUFFOLK

Foreword

By the General Editor

The provision of an absolutely reliable supply of seeds for sowing is of the very greatest importance to farmers, market gardeners, and private gardeners alike, and one is happy to feel that the past twenty years have seen a great change for the better. As Mr. Monro shows in Chapter Five of this book, a protective Act was felt to be necessary before most of us were born—in 1869—at a period when adulteration was rampant and few even among seedsmen knew much about the seeds they sold. In this country the change during the present century has been largely due to the provisions of the Seeds Act, 1920, and the interest aroused by the educational efforts in connection with this measure; but even before it came into force the seed trade had for some years been putting its house in order, and many big seeds merchants had their own testing stations, while others made good use of the Swiss Seed Control Station at Zürich under Dr. Stebler.

At about the time the old Act of 1869 was passed, Holst in Copenhagen and Nobbe at Tharand in Saxony introduced a more or less definite scheme of seed testing, and it was not long before the subject became a science of importance throughout Europe. Thereafter education in the botanical and practical applications of seed testing grew apace, and the Continent now possesses many important stations, of which the writer was privileged to visit nine, on behalf of the Ministry

of Agriculture, in 1913, a report being issued in 1914. It was a happy event when an official seed-testing station was inaugurated in this country in 1917, largely, if one may record it as an historical fact, through the energy of the late Sir Lawrence Weaver when at the Food Production Department, although a decision to found one had been taken more than three years earlier, the war delaying fruition.

. An up-to-date, thoroughly reliable, and well-written book on seeds was certainly needed, and the main author is to be congratulated on having dealt with a difficult and technical subject in a most attractive and practical way, and on having provided first-class illustrations. An account of the working of the Seeds Act, 1920, may perhaps afford less scope for a fascinating story, but it is an informative and interesting account of good work well done. The volume as a whole should be of very great value and interest to farmers, seedsmen, gardeners, and students. H. C. L.

SURBITON,
July, 1937.

NOTE.—This Second Edition of the late Mr. S. P. Mercer's book has been prepared by Mr. A. Eastham, D.S.O., M.C., B.Sc., N.D.A., Chief Officer of the Official Seed-Testing Station, Cambridge. Many necessary changes have been made to bring the work into line with present conditions, but Mr. Eastham observes that he has refrained from making any alteration that did not seem to be essential. The fabric of the book itself is still Esher Mercer's. H. C. L.

January, 1948

Preface

This book essays the rather delicate task of giving the non-technical an outline idea of the beautiful mechanism of reproduction in plants, setting before the agricultural student a syllabus of essentials to his seed studies, offering a skeleton guide to the professional business of seed-testing, and indicating to the farmer or gardener the means available to him for cheap insurance of braird. The author is well aware of the ambitious character of his proposal and of many shortcomings in the product; he hopes he has not been too unsuccessful in his attempt at readability, for the sake of which he has sometimes jettisoned informativeness but not, it is hoped, accuracy of view. No apology is made for the use of technical terms: precision is impossible without them, and there is no more reason why an engineer should not understand mitosis than why a botanist should not comprehend the parallelogram of forces when, in either case, the proposition is explained.

The author acknowledges gratefully the help he has had in the preparation of the manuscript and in careful proof-reading from his colleagues: Patrick Lineham, Arthur Muskett, Ian Seaton, and Agnes Brown. The reader is indebted to Robertha Stuart for all the photographic illustrations; the remainder of the figures are by the author, who also stands in debt to his wife for the labour of indexing.

The drawings of crop and weed seeds present detail as seen

through a × 12 pocket lens. Practically all the detail portrayed can be seen through a × 8 lens, which is ordinarily of sufficent strength for an analyst's purposes.

S. P. M.

CARRICKFERGUS,
May, 1937

Contents

CHAP.		PAGE
	FOREWORD	v
	By the General Editor, H. C. LONG, I.S.O., B.Sc. (Agric. Edin.)	
	PREFACE	vii
	LIST OF ILLUSTRATIONS	xi
I.	THE NATURE OF A SEED	1
	Immortality	1
	Seed Formation	1
	The Embryo	3
	Seed Structure	7
	Ripening, After-ripening	8
	Longevity	11
	Hard Seed	14
	Germination: Oxygen, Water, Temperature, Vernalization	16
II.	COMMERCIAL SEED PRODUCTION	20
	Seed Growing	20
	Seed Storage	23
	Shipping	24
	Seed Cleaning	27
	Disposal of Cleanings	34
	United Kingdom Seed Supplies	36
	Home-grown Supply: Grasses, Clovers, Lucerne, Calcicoles, Root Crop Seeds, Vegetables, Flax .	36
	Indigenous Strains: Certification . . .	43
	Overseas Sources	44

CHAP. PAGE

III. Seed Testing 46
Purpose 46
Technique 48
The Purity Test: Injurious Weeds, Other Weeds, Useful Impurities, Inert Matter. Technique of Purity Test: Sampling, Analysis, Weight, Bushel Weight, Moisture, Diseases, Provenance . . 48
The Germination Test: Conditions, Temperature, Oxygen, Duration; Apparatus . . . 67
Technique of Germination Test . . . 71
Interpretation of Results 73

IV. Crop and Weed Seeds 78
Crop Seeds:
Cereals 78
Root and Vegetable Crops 83
Grasses 86
Leguminous Crops: Clovers, etc. . . . 94
Pulse Crops 99
Miscellaneous Legumes 100
Miscellaneous Crops 100
Weed Seeds 101

V. The Seeds Act, 1920: Its Provisions and Administrations 118
By A. W. Monro, C.B., Late Principal in charge of the Commercial and Seeds Branch, Ministry of Agriculture and Fisheries

Appendix
I. Crop Seeds: Physical Data 138
II. Notes and Data for Practical Seed Testing . 140
Index 146

List of Illustrations

FIGURE		PAGE
1.	Cell Division and Embryo Formation . . . Pollen structure, Pollen germination, Wheat embryo sac, Ovary and ovule structure at fertilization. Normal cell division, Development of dicotyledon embryo from fertilized egg-cell.	4
2.	Types of Seed Structure and of Germination . Wheat, Onion, Red Clover, Mangold, Pea.	6
3.	Moisture Relations in Ryegrass	26
4.	Principles of Seed-Cleaning Machinery . .	28
		FACING PAGE
5.	Seed Testing Apparatus and Technique . . Sampling, Dodder Machine, Chondrometer.	36
6.	Seed Testing Apparatus and Technique . . Diaphanoscope, Aspirator.	37
7.	Seed Testing Apparatus and Technique . . Gentner test, Germination in sand, Rodewald germinator, Jacobsen germinator, Hearson cabinet.	52
8.	A Modern Seed Testing Station . . . . Purity Laboratory.	53
9.	A Modern Seed Testing Station . . . . Purity test in progress.	53

FIGURE FACING PAGE

10. Cereal Seeds 68
Wheat, Barley, Oats, Rye, Maize.

11. Root and Vegetable Crop Seeds . . . 69
Crucifers, Umbellifers, Chenopods, Onion.

12. Forage Crop Seeds—Grasses 84

13. Forage and Fibre Crop Seeds 85
True Clovers, Calcicoles, Miscellaneous Legumes, Flax.

14–33. Weed Seeds 100
Ranunculaceæ, Papaveraceæ, Fumariaceæ, Cruciferæ, Violaceæ, Resedaceæ.

34–53. Weed Seeds 101
Caryophyllaceæ, Malvaceæ, Geraniaceæ, Leguminosæ, Rosaceæ, Onagraceæ.

54–75. Weed Seeds 116
Lythraceæ, Umbelliferæ, Rubiaceæ, Valerianaceæ, Compositæ.

76–96. Weed Seeds . . . . . *between* 116/17
Compositæ (contd.), Primulaceæ, Convolvulaceæ, Boraginaceæ, Scrophularineæ. Labiatæ.

97–112a. Weed Seeds . . . . . *between* 116/17
Verbenaceæ, Plantagineæ, Amaranthaceæ, Chenopodiaceæ, Polygonaceæ.

113–129. Weed Seeds 117
Urticaceæ, Euphorbiaceæ, Juncaceæ, Cyperaceæ, Gramineæ.

Chapter One

The Nature of a Seed

Immortality. Evidence has recently been produced to show that the duration of life on the earth of any *species* of flowering plant is about twelve million years. We are in the habit of thinking of plants and animals as individual beings each having an allotted span of life, long or short, but inevitably culminating in death. This is a misleading idea. We all recognize that the natural objective in life of a plant or an animal is to reproduce itself. A moment's consideration shows that if it succeeds in this, the essential part of the organism does not die. In the process of reproduction an actual living portion of the essential *protoplasm* of the parent enters into the formation of the offspring—into that of the various organs which " grow up " into the new plant or animal. Reaching maturity, this daughter plant or animal reproduces again in the same way—transmitting a portion of *still the same* protoplasm, *still the same* life, to a granddaughter. Thus not only the " spark of life " but the actual physical material of which the organism is constructed is essentially continuous from generation to generation throughout a line of descent, even though that line should extend to twelve million years. What is the machinery of the process? In flowering (i.e. seed-bearing) plants it is in broad outline as follows.

Seed Formation. In the *fertilization* process, protoplasm from the male *pollen grain* unites with protoplasm of the female *ovule* contained within an *ovary* either of the same flower, a different flower on the same plant, or a flower on another

plant. In the first two instances *self*-fertilization results, in the last instance *cross*-fertilization. Cross-fertilization may often be achieved between plants not of the same species—for example, the loganberry arose by cross-fertilization between a raspberry and a blackberry. It may be brought about by natural agencies—wind, insects, etc.—and may then sometimes be very detrimental, as when a turnip grown for seed is "crossed" by rape, the *hybrid* produced is useless. As a general rule cross-fertilization is practicable only between close relatives.

The specialized protoplasmic bodies that take part in this *sexual union* are the *nuclei*. Each cell taking part in the architectural structure of the plant normally contains one such nucleus, but the reproductive cells at maturity contain more—the male cell three and the female seven, of which seven one is the product of reunion between two of the eight present at an earlier stage. Coalescence of *one* of the three male nuclei with *one* of the seven female nuclei constitutes the essential act of fertilization, and the resulting compound nucleus subsequently gives rise to the *embryo*—the new young plant contained in the seed.

Each active nucleus contains a number of intertwined thread-like bodies, the *chromosomes*, in which reside the factors controlling the characters of the plant. The precise nature of these factors is in doubt, but seems to be connected with the manner in which the atoms are arranged in the molecules. The number of chromosomes is the same in every ordinary body cell of all plants of the same species, and the various shapes and sizes of chromosome that make up the complement of a given cell are repeated in all other body cells. The character factors are also the same in all "opposite number" chromosomes in different cells. This is ensured during ordinary cell division (by means of which growth is carried on) by the longitudinal splitting of every chromosome in the original cell, and the apportionment of one-half of each to each of the two new cells. Thus a complement of new chromosomes similar in number, shapes, sizes, and character-constitutions to those of the original cell appears in each new cell.

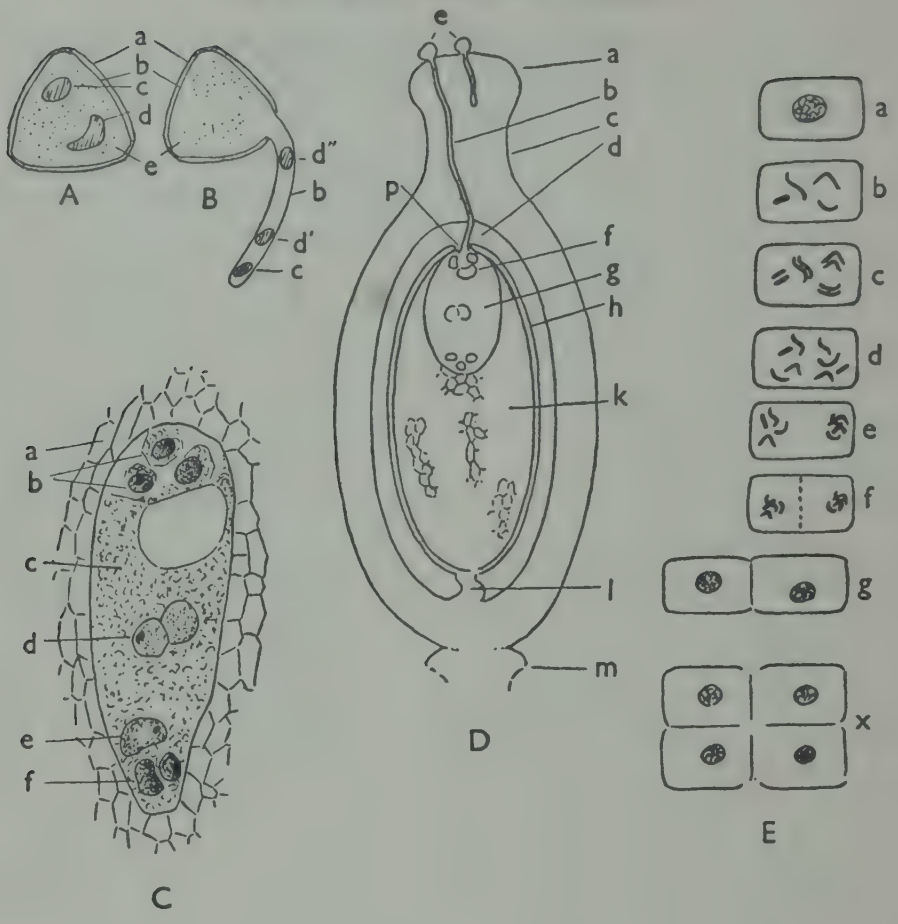
In the process of maturation of the male and female *sexual*

reproductive cells, however, a different kind of cell division takes place in which the longitudinal splitting of chromosomes does not take effect. Hence the number of chromosomes available for each new cell is only half the number present in the old cell, and so the matured reproductive cell contains only this reduced number. By union of the male and female reproductive cells at fertilization the chromosome number of the compound cell (the *zygote*), from which the embryo is developed, therefore again returns to the normal, half the chromosomes present being contributed by the male and half by the female parent. Since the factors responsible for the characteristics of the species are carried by the chromosomes, it is easy to see how those of both parents may be mixed in the offspring. It will be observed that if the "*reduction division*" mentioned did not take place, the number of chromosomes in every cell of each generation would be double that in the preceding generation, and in a very few generations an entirely impossible congestion would result!

The chromosome number in the reproductive cell of a species is commonly spoken of as the *haploid* number, and the number (twice as many) in the body cell as the *diploid* number. In writing, these two numbers are often expressed as n and $2n$ respectively. Thus the statement that "in *Homo sapiens* and *Nicotiana tabacum* $2n = 48$" implies that in man and in tobacco the number of chromosomes in the nucleus of each body cell is 48 and in that of each reproductive cell 24.

The Embryo. The development of a new plant, with all its various organs specialized in structure and tuned so exactly, each for its particular purpose, from one single (zygote) cell, is a process of amazing intricacy. It is of course the outstanding wonder of life. From the purely mechanical point of view most of its stages can be followed under the microscope, but the directing influence is almost entirely uncomprehended: compared with this process the difference between life and death is a matter of simple physics.

After fertilization the new compound cell (still within the ovary of its mother) first divides into two daughter cells. One of these daughter cells forms a stalk for attachment of the young embryo to the surrounding tissue of the parent. The



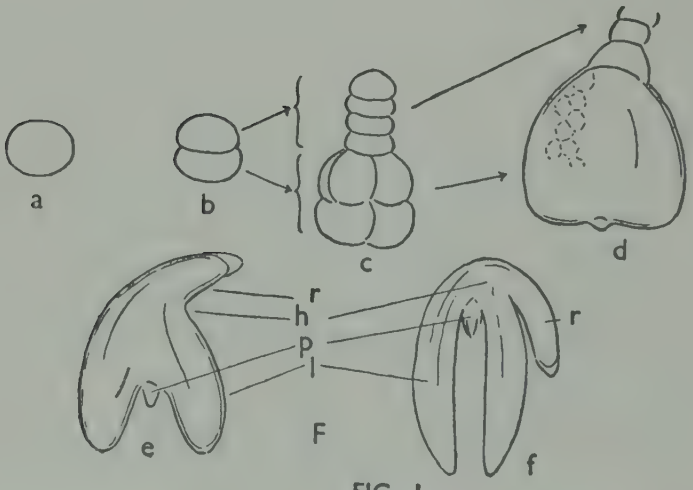


FIG. 1.

[*Explanation of Diagrams at foot of page* 5

other redivides again and again to form successively two, four, eight, sixteen, etc., further cells, resulting in a tiny solid mass of new tissue. At a relatively early stage in the growth of this mass indications can be observed of differentiation into three principal layers of slightly different character and appearance. From the outer, middle, and central masses respectively the skin, outer flesh, and central cylinder of the embryo root and shoot are later developed. In the central cylinder strands of elongated cells begin to appear, branching and extending later to form the *vascular system* (arteries and veins) of the grown plant, with ramifications reaching to the extremities of roots, branches, leaves, flowers, and fruit. Fig. 1 will make these early stages clear. In essentials the process is similar in the two main groups of seed-bearing plants with which we are concerned—*monocotyledons*, in which the embryo carries one seed-leaf, and *dicotyledons*, in which it has two. There are smaller groups in which the seed has no seed-leaf (acotyledons) or several seed-leaves (polycotyledons). Normally there is one main bud, the *plumule*, from which the stem and branches arise when the seed germinates, and one main root, the *radicle*, from which the mature root system arises. There are instances in which there appear to be several *primary roots*; in the germination of the wheat grain, for example, three roots appear to emerge together, but in reality the central is slightly ahead of the laterals, which are branches from it (Fig 2).

A, B—Germination of pollen grain.

a, outer wall; *b*, inner wall; *c*, vegetative nucleus; *d*, *d'*, *d''*, generative nuclei; *e*, cell protoplasm.

C—Embryo sac.

a, cell tissue of ovule; *b*, antipodal nuclei; *c*, protoplasm; *d*, dual primary endosperm nucleus; *e*, oosphere (egg-cell); *f*, synergidæ (guide cells).

D—Longitudinal section of pistil at fertilization.

a, stigma; *b*, pollen tube; *c*, style; *d*, ovary; *e*, pollen grains; *f*, oosphere; *g*, embryo sac; *h*, wall of ovule; *k*, cell tissue of ovule (nucellus); *l*, stalk of ovule (funicle); *m*, receptacle of flower; *p*, micropyle (pore).

E—Diagram of cell division process.

a, normal cell with resting nucleus; *b*, separation of chromosomes; *c*, splitting; *d*, segregation of halves; *e*, *f*, reassociation in two groups; *g*, daughter cells divided; *x*, tissue of cells similarly formed and undifferentiated.

F—Development of embryo from fertilized oosphere.

a, zygote; *b*, first division; *c*, stalked cell mass; *d*, initiation of plumule and cotyledons; *e*, appearance of zones in tissue; *f*, fully developed embryo; *r*, radicle; *h*, hypocotyl; *p*, plumule; *l*, cotyledon(s).

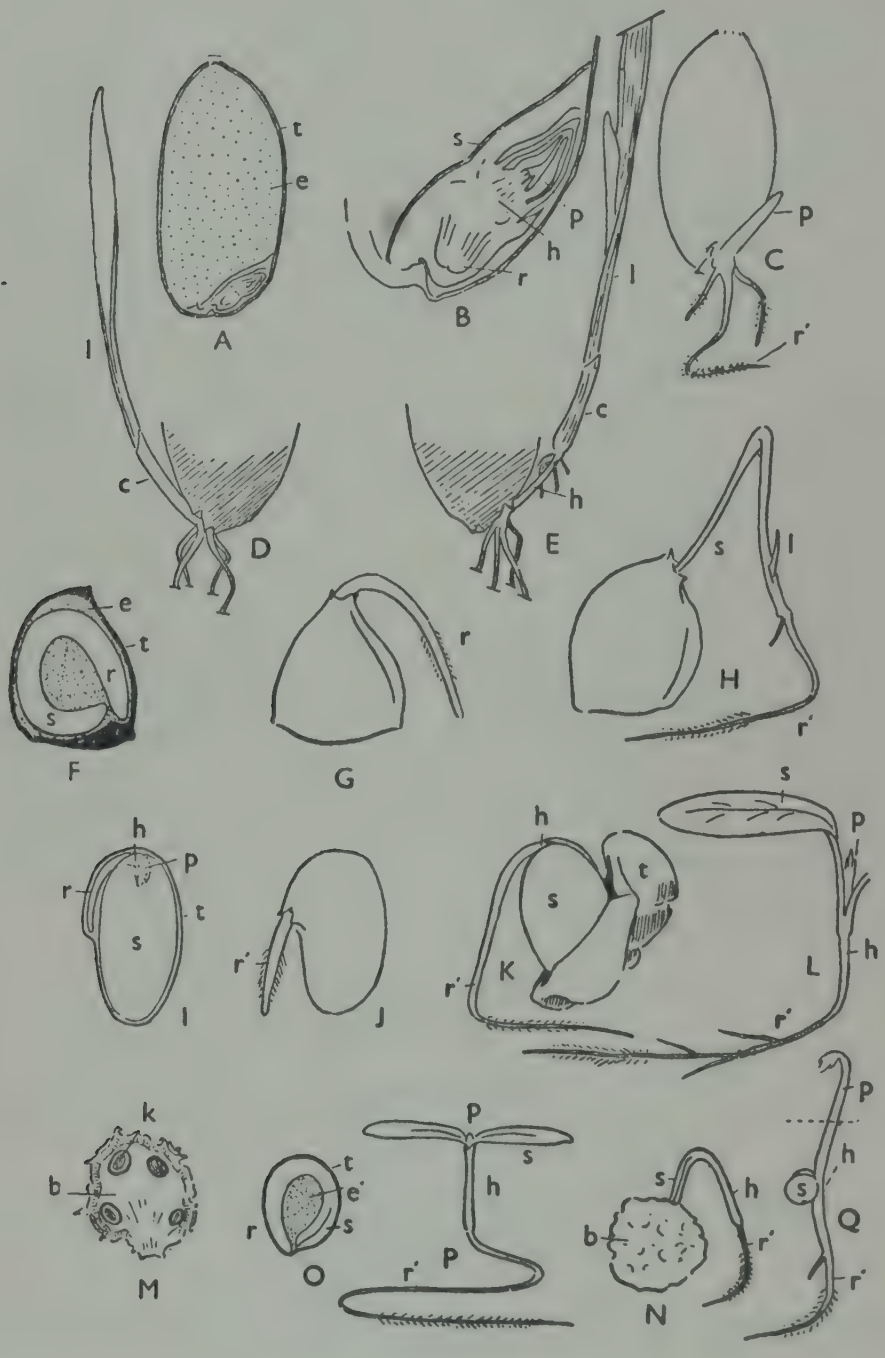


FIG. 2.

[*Explanation of Diagrams at foot of page 7*

Seed Structure. In the typical mature seed these parts are to be distinguished (Fig. 2):

(i) The skin or *testa*, consisting of several layers of cells. In cereals this is permanently united with the wall of the ovary in which the seed developed.

(ii) The *plumule* or shoot, consisting of a very short stem bearing young leaves in the form of a bud.

(iii) The *radicle* or root, on which branches are not recognizable at this stage. A protective *root-cap* is sometimes identifiable, covering the extreme tip of the radicle.

(iv) The one or more *cotyledons* or seed-leaves. In dicotyledons such as beans or clover these are thick, fleshy structures that act as storehouses of food for the use of the young plantlet when the seed germinates. In monocotyledons the seed-leaf is less fleshy and acts rather as a transmitting organ than as a storage vessel, absorbing food material from the (separate) storage tissues and handing it on to the developing embryo. Grasses constitute a special group in which the seed-leaf analogy is less clear and is still in dispute. Probably the cotyledon is represented by the plate of tissue dividing the plumule and radicle from the starch store.

In clovers and similar plants the cotyledons come above ground when germination takes place and form the first pair of green leaves; such behaviour is styled *epigeal*. In peas and many other examples the seed-leaves remain below ground and never function as green foliage leaves; these are *hypogeal*. The plumule, radicle, and cotyledon(s) together constitute the *embryo*.

(v) Food material, stored dry, for the use of the young embryo in germination (cf. the yolk of an egg) is packed either in the cells of the fleshy cotyledons (*ex-albuminous* seeds, e.g. bean, clover) or in the cells of separate storage tissue (*endosperm*) outside the embryo (*albuminous* seeds, e.g. onion, wheat). The endosperm tissue arises by division and redivision of the *primary endosperm nucleus*, which was mentioned earlier as one of the seven nuclei in the female embryo cell, formed by reunion of two among eight. In many instances this tissue formation is known to be preceded by " fertilization " of the double nucleus by amalgamation with a second nucleus of the three originating

---

A–E—Wheat: A—longitudinal section of grain; B—embryo; C—germination; D—one-leaf seedling; E—adventitious root development. F–H—Onion: F—longitudinal section; G—germination; H—seedling. I–L—Red Clover: I—longitudinal section; J—germination; K—germination, later stage; L—seedling. M–P—Mangold: M—section of " cluster "; N—germination; O—longitudinal section of seed; P—seedling. Q—Pea seedling with hypogeal cotyledons.

b, receptacle of flowers; *c*, coleoptile; *e*, endosperm; *e'*, perisperm; *h*, hypocotyl; *k*, submerged seed; *l*, first foliage leaf; *p*, plumule; *r*, radicle; *r'*, primary root; *s*, cotyledon(s); *t*, testa.

in the pollen grain. The whole process, consisting of union of first male nucleus with female " egg " nucleus and union of second male nucleus with the primary endosperm nucleus, is then referred to as *double fertilization.*

(vi) *Perisperm* is very occasionally present in the maturing seed. When present it represents a supplementary food store, and consists of the unused remnant of the tissue upon which the embryo fed during its post-fertilization development—that is, the tissue in which the large cell containing the " egg " nucleus was embedded. Perisperm may conveniently be seen in pepper corns.

Ripening. This is a vague term, and the popular understanding of the word is preferable to scientific attempts to codify it. Ripening is a gradual process, and in it there is only one stage that can be fastened upon as a finite point—that is, the point of "*germinating ripeness.*" This term explains itself, a seed being germinating ripe when it is ripe enough to germinate. This may be before it is shed from its parent plant, or it may not be for more than a year afterwards. Approximately the stages (not necessarily serial in time) making up the process of ripening are (i) completion of embryo development, (ii) formation of storage tissue, (iii) transport of food material from other parts of the plant to the storage tissue, (iv) conversion of food to an insoluble (in water) form and deposition in the storage tissue, (v) formation of ferments in an inactive condition, which when activated by warmth and moisture will digest the stored food, (vi) desiccation (drying).

The ripening seed breathes, just as any living part of a plant must breathe, but the rate of respiration (breathing) slows down as full ripeness approaches and eventually *almost* ceases. Fully mature and ripe seeds have been kept in a vacuum or in an inert atmosphere of nitrogen for considerable periods without harm. Given a breathable atmosphere such as ordinary air, the rate of respiration is increased by warmth and the presence of moisture. Hence the undesirability of storing seed in too warm or too damp a place. Seeds breathing rapidly will not remain alive so long as similar seeds breathing very slowly. The discouragement of fungi (mould) is of course a further reason for avoiding such conditions. The two conditions warmth and moisture, are to a considerable degree inter-

dependent for their effect. If one is kept low the other may rise high without harm. Thus if ryegrass seed is soaked in water much of it will be killed by a temperature of 40° C. applied for a few hours, but if the same seed is normally " dry " (i.e. 12–13 per cent. of moisture) it may be kept at 40° C. for several days without injury—indeed, freshly harvested seed is often improved in quality by this treatment.

The amount of water retained in its tissues by a fully mature and ripe seed varies according to the species and the climate in which it is produced. For a large number of species, including many common agricultural sorts, under United Kingdom conditions, the percentage ranges between 10 and 30. It is not uncommon for *freshly harvested* grass seed, for instance, to contain as much as 25 or even 30 per cent of moisture, but after lying for a few weeks in store and maturing the same seed will show only some 13 per cent. In some countries Government regulations control the permissible percentage of moisture for seed that is to be shipped: in such instances kiln-drying must be resorted to if the " natural " percentage is above the permitted maximum.

The ripening changes that have so far been described are visible and determinable by microscope and chemical test. Parallel with them is a series of invisible changes the exact nature of which is unknown. These constitute the process called *after-ripening*, and until it is complete the seed is not germinating ripe—it will not grow, although visible requirements may be met. Usually after-ripening proceeds alongside " visible " ripening, so that as soon as the seed is " visibly " ripe it is capable of germination. There are, however, many species in common use in which after-ripening may not be complete by the time the seed reaches the desiccation stage, and with them a period of rest is essential before the seed will grow. Oats, especially black winter varieties, very commonly exhibit lack of after-ripening and incapacity to grow when freshly harvested. With spring varieties the necessary changes have usually taken place in the stack, and hence spring varieties are less troublesome in this respect. While clover seeds seldom require any appreciable rest period, those of many dicotyledons do. The necessity of such a period, however, seems to be more

frequent amongst monocotyledons, the seeds of both ornamental and agricultural species often presenting difficulties.

Cereals grown in northern climates, and more especially after a cold, wet harvest, are a constant source of trouble to those making germination tests. Sometimes special conditions other than mere rest seem necessary to induce complete after-ripening. In the South American grass *Chloris ciliata*, for example, brilliant sun illumination is demanded, and in certain primrose species and gentians frost appears to be necessary.

The changes constituting after-ripening are physical rather than chemical or anatomical, and appear to consist of changes in the architecture of the protoplasmic molecule—i.e. presumably, a rearrangement of the atoms constituting the molecule. The exact nature of the changes is not known, but it seems clear that they are irreversible and are part of an extended series of changes that proceed throughout the life of the seed and continue after it ceases to be capable of growth and is called " dead." At a certain point in this series of changes the seed becomes capable of germination, and is then described as germinating ripe; at a later stage in the same continuous series of changes the seed again becomes incapable of germination, and this point we call death. Manifestly it is commercially valuable as seed only while it journeys between these two points. Chemical changes that accompany these physical developments and continue after so-called death result eventually (in some thousands of years) in the carbonization of the seed—a charcoal model of it remaining, as may be seen in the cereals unearthed from very ancient Egyptian tombs.

Seeds enjoying a rest period are described as *dormant*. Dormancy may, of course, be artificially prolonged, by withholding the moisture or heat or oxygen necessary for germination. On the other hand, to break a natural dormancy and induce a seed to grow " before its time " is a matter of the greatest difficulty. Indeed, it is probably safe to say that it cannot really be done and that any apparent success attending seed treatment designed to induce premature germination is due in fact to a hastening of the after-ripening changes, not to any elision of them. This is perhaps an academic distinction—the effect is the same.

Longevity. In view of what has been said, it is not surprising to find a period in the series of physical changes towards the death-point during which the seed is still capable of growth, but not of ready or vigorous growth. This is the period of *senility* or *senescence*. It may be an extended period of slow loss of vitality, as in, say, red clover, which may live eight or ten years, or a brief season of rapid weakening, as in parsnip seed, which is commonly useless at one year old.

The importance of the varying capacity of different species to retain vitality—to seedsman, gardener, farmer, and forester alike—is obvious. Among crop seeds the value of parcels kept " over-year," i.e. until actually in the second year of their age, must depend very largely on this capacity. A certain amount of commercial seed, sometimes a very large amount, is over-yeared every season, the quantity depending on the amount harvested and the season's demand. Crop seeds are occasionally called upon to do their best when much more than two years old. As to weeds, it is patent that those that produce seeds capable of long life are much more potentially harmful than those producing short-lived seeds.

It is easy to understand that the problems of longevity—specific and varietal differences, factors assisting or interfering with retention of life, methods of fostering it artificially—have interested investigators for many generations. Zoroaster, writing about eight centuries before the Christian era, and Theophrastus five centuries later, referred to it, the latter examining the then available evidence in some detail. To these a very extensive list of modern workers' names could be added, perhaps the most outstanding being Strickland and his fellow members of a British Association Committee set up in the middle of the nineteenth century, Ewart, Becquerel, Giglioli, Dorph Petersen, Winifred Brenchley, and Crocker. These workers have studied the effects of natural and controlled artificial conditions of storage upon length of life in, collectively, a large number of species.

The British Association Committee, using some 200 species, found those of the pea family (Leguminosæ) most notable for longevity, several species being capable of life up to nearly half a century. Their work suggested that the most critical ages

for many species were three years and eight years—ninety-seven species losing their germination capacity at the third year, only nine at four years, three at five years, three at six, but seventy at eight years of age.

Miss Brenchley at Rothamsted conducted trials that have become classical upon the numbers and viability of arable land weed seeds to be found in soil under turf of known age. Land known to have been ten years under grass provided a total of about 400 seedlings of arable weeds from a quarter of a cubic foot of soil; a thirty-two-year-old turf field yielded seventy-four, and thirty were obtained from soil covered fifty-eight years by grass. Soil from an arable field tested at the same time gave a few less than 800 seedlings, so that roughly speaking about half the seeds of common types appear to have lived ten years and about one twenty-fifth of them for nearly sixty years. The seedlings obtained from soil at various depths up to 1 foot were separately counted, and it was found that where the land had been under grass for long periods (thirty years and upwards) the greater number of the viable seeds were in the lower layers at depths of 6 to 9 inches, suggesting that quiescence of conditions and protection from *changes* in warmth, moisture, and aeration exercised a definite protective effect. As many as eleven different species had survived in the soil undisturbed for fifty-eight years, against only twenty appearing in that still cultivated, and fourteen in that ten years under grass.

Dorph Petersen conducted careful experiments upon the effect of digestion by farm animals upon common weed seeds—an important matter, for manure-heaps play a prominent part in distribution and perpetuation of weeds. He found about half of the seeds of ribgrass (*Plantago lanceolata*) and a quarter of those of mayweed (*Matricaria inodora*) germinable after passage through the digestive tract of a cow. Again, about half the seeds of sheep's sorrel (*Rumex acetosella*) and of fat hen (*Chenopodium album*) were alive after passage through a pig. A much smaller proportion survived digestion by a fowl, but here the grinding action of the gizzard must be borne in mind. American work suggests that the digestive system of the horse is less effective than that of the cow in destroying weed seeds. It would thus appear that seeds given to stock in fodder, as well as

those occurring in litter, play an important part in contamination of the manure-heap. It must be observed, however, that a material proportion of the weed seeds finding their way into manure perish by reason of the moist heat generated there by fermentation, though it is known that many of the hard-shelled types, like docks, sorrels, and fat hen, can withstand even these conditions very well.

Investigations have been made by Ewart, Becquerel, and others concerning the effects of controlled conditions, from which emerges the general conclusion that seeds may be kept for considerable periods (more than a decade) in inert gases such as nitrogen or carbon dioxide, and even in a vacuum, if kept dry, cool, and undisturbed. Stability of conditions seems to be a very potent factor, and probably this accounts for successful survival at depths of several inches in the soil.

Fabulous stories are current concerning the germination of seeds of immense age. Wheat grains taken from Egyptian tombs are often credited with vitality. Although this is quite untrue, it is a legend that never seems to die, and year after year inquiries are received concerning so-called " mummy " wheat. When examined the embryos of genuine mummy wheat are found to be incapable of germination, and grains placed in test rapidly decay. Actually wheat is a comparatively short-lived seed, and under ordinary conditions of storage twenty-five years may be considered its maximum life span. The agricultural value for seed purposes is, of course, a very much shorter period. The oldest living seed of which there is authentic record is probably that of *Nelumbium speciosum* (the Sacred Lotus), recently roused out by Dr. Ohga from Manchukuo peat beds where it had certainly lain several hundred years. This seed is invested in a shell so hard that soaking in concentrated vitriol proved a necessary preliminary to germination; and peat is an excellent preservative material. Instances of lesser, but nevertheless considerable, longevity are familiar to most of us. Charlock and poppy seeds do quite frequently germinate in enormous numbers in soil that is broken up after lying for thirty or more years undisturbed (witness the Flanders poppy), and a cut- or burnt-over forest or clearing will often " spontaneously " produce a sea of pink willow herb, hence the name

"fire weed" given to *Epilobium angustifolium* in North America. Certain families of plants are specially notable for longevity in their seeds, among them the poppy, turnip, and clover families. The last-named represents a special group.

Hard Seed. In clovers and other small *legumes* we commonly meet with individual seeds that do not swell if immersed in water. This means that they do not imbibe any of the water, and consequently do not grow. With well-ripened seed the majority, if not all, are alive, and a pinprick or scratch will induce growth. Immature or poorly developed seeds may remain hard in test, and yet prove incapable of germination even though the seed-coat be punctured. Hard seeds have a thicker *cuticle*, or horny water-resisting layer, on the outside of the testa (seed-coat) than the average of their kind, and, being thus protected, can frequently remain alive much longer than seeds less well armoured. Among commercial legumes the small-seeded species exhibit this capacity for "hardness." One rarely meets with it in peas or beans, but it commonly appears in lucerne, trefoil, and the true clovers, being again more general in the smaller-seeded species of the last-named group, such as white and alsike, than in red or crimson clovers, which have larger seeds. Hot, dry weather during ripening, and over-ripening, are conducive to the formation of hard seed. Hence *wild* white clover, which is a mixture of strains that ripen irregularly, commonly contains a higher proportion of over-ripe grains, and thus of hard individuals, than Dutch white, which has been reduced by repeated cultivation to a more nearly uniform mixture of strains. Wild white samples may occasionally be found to contain 90 per cent of hard grains, average figures being 5–15 per cent. In commerce, parcels of clover containing material amounts of hard seed are *scarified*, and thus rendered pervious to water, by abrasion against a rough surface in special air-blast machines. With irregularly ripened bulks scarifying sometimes gives a disappointing result, for the subsequent germination may be lower than the combined germination and hard-seed content before scarification. This is not due to faulty testing, but to the fact that some of the hard seeds are not viable.

There has been much controversy regarding the value, under natural conditions, of hard seed. The view has been held that hardness is a provision against accident, the theory being that if the crop fails because the seedlings are killed off by adverse conditions such as drought the hard seeds, not having germinated, are uninjured and remain in the soil ready to sprout when more clement conditions prevail. To make them incapable of absorbing moisture, whether it is there or not, seems a somewhat strange means of achieving this protection for the species! It has been argued, on this theory, that hard seed should be regarded as germinable for the purpose of declaring the percentage germination capacity of a sample. Under the rules of the International Seed-Testing Association a compromise is adopted: With lucerne the total percentage of hard seeds, one-half for red clover and one-third for other legumes, may be added to the actual germination percentage (after stating both figures separately) for the purpose of calculating the "real value" of the sample, i.e. the combined figure expressing purity and germination together, arrived at by multiplying purity per cent by germination per cent and dividing the product by 100. For the purpose of declaration under the Seeds Act, 1920, in trading within the United Kingdom it is not permissible to add any part of the hard seed percentage to the germination figure; both figures are, or should be, stated separately.

In practice, if they are kept immersed it is found that in the true clovers from 35 to 45 per cent of the seed remaining hard at the conclusion of the ten-day germination test will soak in one year, while in trefoil and lucerne practically all will imbibe in that period. The international rule on the matter is therefore reasonable, though the permissible addition might perhaps be augmented somewhat for trefoil. A splendid example of the patience required in scientific inquiries is furnished by a classical trial with hard seeds conducted by Dr. Nobbe, of Tharandt in Saxony. He set various lots of " hard " red clover seeds to soak in distilled water and counted off periodically those which had swollen. After *forty years* he issued an *interim* (!) report showing that roughly one-third of the seeds became permeable in one year and another one-third in the next thirty-

nine years. Similar experiments conducted by the author with white and alsike clovers (so far for only twenty years) show closely similar results, the proportion soaking within one year varying between 33 and 44 per cent in different samples, alsikes usually showing rather higher figures than white clovers. From these trials, therefore, as well as from the point of view of common sense, it seems clear that under farming conditions no more than a third of such seeds are likely to be of practical value, for it cannot be claimed that in the usual course seed germinating more than a year after sowing is of much value.

Germination. Four requirements are commonly recognized as essential for the germination of a ripe seed, namely: (i) oxygen, (ii) water, (iii) a sufficient degree of warmth, and (iv) the seed must be alive—a factor often forgotten! To these the reader will now add (v) after-ripening, bearing in mind that this is often completed without any rest period following " visible " ripeness.

Oxygen. In ordinary circumstances oxygen is of course supplied by air. Of ordinary air, oxygen forms about one-fifth. In the soil the composition of the air between the mineral particles differs a little from that of atmospheric air, containing slightly more carbon dioxide (carbonic acid gas) and slightly less oxygen; but unless air is excluded, as, for example, in an undrained soil by waterlogging, there is ample oxygen for the purposes of germination. Even if air be totally excluded, vigorous seeds will frequently germinate making use for the purpose of the oxygen generally to be found dissolved in water, especially in rain-water. Moreover, the cell tissue of which the seed is composed is permeated by air-passages and the very small amount of air contained in these may be enough to enable the seed to begin growth. In the absence of an external supply of oxygen, however, development does not proceed very far. The oxygen is used by a seed in the early stages of growth for the purpose of *respiration*—in effect for *burning food* to provide energy to perform the *work* of growth, just as we ourselves breathe in order to burn food in our own bodies to give us energy to walk (or to write text-books!). The process is indirect, but that is what it amounts to.

Water. Animals and plants, including seeds (which are miniature plants), maintain life in the jelly-like *protoplasm* contained in all living cells. For the maintenance of life in that protoplasm water is an absolute essential. It has been pointed out that seeds in a " dry " state are not in fact entirely dry—some water always remains. If they are completely dehydrated they are killed. Protoplasm in a resting condition can remain alive with a minimum supply of water, but a plentiful supply must be present to support activity. Clearly the protoplasm must be active in such a process as germination and growth. Hence, patently, a good water supply is essential. In healthy soil the necessary water is absorbed from the film that normally surrounds each particle. It chiefly enters the seed through the *micropyle*, but is absorbed to a lesser extent all over the seed surface. In instances such as beet and mangold, where the seed is enclosed in a spongy receptacle, and in grasses, where the kernel is held between chaffy *glumes*, the latter act as absorbing and storing organs for water, which they pass on at a reduced and regulated rate to the seed within. Such seeds are less affected by variation in water supply during germination than naked seeds such as clovers.

Normally, seed does not need to be fully soaked in order to grow. Indeed, some species, such as cocksfoot grass, resent a too-profuse water supply and germinate sulkily therein. The water-absorbing relations of grass seeds in particular are very involved, and will be referred to in a later section when shipping is under consideration. Besides being an essential factor in the activation of protoplasm, water is of course required as an agent of transport to carry dissolved food and food products from place to place within the tissues. It is naturally the chief constituent of the sap either of a seedling or a mature plant, as of the blood of animals. In view of what has been said under this and the preceding head, it is interesting to note that distilled water, which contains no air, is definitely less satisfactory than tap- or rain-water, which are aerated, for use in germination under laboratory conditions.

Temperature. Practically nothing will grow at freezing temperature and nothing at boiling heat, but between these there is a wide range of temperatures *tolerated* if not enjoyed

by one or other species. Agricultural and garden seeds in general prefer relatively low temperatures of between 18° and 30° C. (= 64½–86° F.), and a large proportion of them will succeed best at about 22° C. (= 71½° F.). Under soil conditions few crops will braird until the soil reaches 8° C. (= 46½ °F.). If a thermometer plunged 2–3 in. in the soil beside a sowing of garden peas in the spring be watched, it will be seen that the peas start into growth when the day temperature passes this point. Under soil conditions seeds are evidently subject to fluctuating temperatures, and in a good many crop species this appears to be an advantage. In the laboratory a number of kinds—e.g. cocksfoot, carrot, parsnip—will grow distinctly better if the temperature of the incubator is deliberately fluctuated within judicious limits than if kept at a uniform temperature. Generally speaking, for laboratory germination, a temperature somewhat too low is better, though it may give results slowly, than one too high. In our soils, of course, too high a temperature is unlikely to exist. In this connexion an important point arises: cereals that suffer from delayed germination, through lack of after-ripening, will give a much higher germination figure within a reasonable period if incubated at a temperature some degrees lower than normal for the species. Thus black winter oats may germinate quite satisfactorily at 18° C. (64½° F.), but will often give much more rapid and better results at somewhat lower temperatures, and if kept at about 5° C. (41° F.) for a couple of days and then brought into the comparative warmth of 18° C., complete germination will follow almost immediately. When facilities for the artificial lowering of temperatures are not available a cool room or cellar will usually give the most satisfactory results. Curiously enough, delayed germination seldom affects grey winter oats to any appreciable extent, nor does it seem to cause any noticeable difficulty in the field. This, however, is probably due to the soil and temperature conditions prevailing at the time of seeding.

Vernalization. It is astonishing how blind we can be to the obvious! Ever since the first day man gathered the fruit of plants for his food he must surely have pondered the machinery of their growth; certainly since plant physiology in the modern

sense took birth from Van Helmont's classical experiment with a willow shoot he has consciously striven to understand the mechanism. All this time he has assumed that bodily growth and the development of a capacity to form fruit were interdependent and *must* advance side by side, simply because they *usually* do so. It remained for the Russian scientist Lysenko, as recently as 1932, to point out that the development of a condition giving *capacity to reproduce* sexually, being largely independent of *growth in size*, could be encouraged to advance while the latter was artificially delayed. The Russian word adopted to describe this artificial separation and speed-adjustment of the two processes was transliterated by German authors to *jarowization*, now translated to the English *vernalization*—i.e. "springification," the artificial inducement during winter of physiological changes that normally occur after sowing in spring.

The process is carried out simply, say, with Russian winter wheat, by spraying the seed with water until it contains half its own weight thereof, placing it in a cool incubator until the *very first* signs of germination appear, then transferring for a period of seven or eight weeks to a cold store where the temperature is too low to allow growth to proceed, but not low enough to cause injury (about 2° C.). During this period of cold storage the *physiological development* towards reproductive capacity advances, while bodily growth of the plant marks time. When, at the conclusion of the vernalization period, the seed is sown, growth in the warm soil proceeds as usual, but the physiological development has "got ahead" of it, and as a consequence seed is eventually produced at an abnormally early stage in the *physical* life history of the plant. The period of growth of the crop in the field is thus shortened (by a term of days), and it appears that under Russian conditions the limits of latitude within which wheat-growing is practicable have been materially extended. So far experiments in America, Great Britain, and elsewhere on similar lines have given mixed and on the whole discouraging results, but this may be due to the fact that crop varieties and conditions are dissimilar to those of Russia than on account of any falsity in the Russian theory.

Chapter Two

Commercial Seed Production

Seed Growing. In an earlier paragraph an outline has been given of the ripening process, and the importance of the invisible factors involved has been emphasized. It is obvious that the farm-scale seed grower has only the less intrinsically important visible changes to guide his judgment in determining the appropriate moment for harvest. He unconsciously uses the visible as a gauge of progress in the invisible developments. In these circumstances it is not surprising if he is sometimes wrong in his judgment, for the relation between the two series, as we have seen, is not hard and fast. The experienced grower, however, is generally " there or thereabouts " right, and perfect exactitude is by the nature of things impossible, since no crop can be expected to ripen all of its seeds at the same moment. Collateral evidence may be of use; for example, the Ayrshire ryegrass grower expect his grass seed and his black currants to be ripe at the same time.

It is evident that no general rules can be laid down, since so much depends on the habits of the crop. The grower " playing for safety " will be inclined to over-ripen rather than under-ripen, on the principle that by leaving the crop standing he will afford the laggards an opportunity of catching up with earlier members. In certain instances this works well enough—for instance, a crop of malting barley must be thoroughly ripened to secure evenness of germination on the malting floor, but in a crop such as turnip, where over-ripening leads to shattering, it will result in heavy loss of seed; while in one like white clover, where it tends to " hardness," it may involve the un-

necessary expense and waste of scarification. Generally speaking, in the straw crops (including grasses) for agricultural purposes the seed need not be dead ripe at harvest. The process is satisfactorily completed in the stook after cutting. The last stage before drying consists of withdrawal of material from the straw to the fruit. This has led to the belief that completion of ripening after cutting is more satisfactorily accomplished if the sheaves be hung head downwards. The author has been unable to find any evidence of this in experiments with several grass species.

In such crops the colour of the fruit and straw is a usual guide to ripeness. Colour here really means proportion of dead mechanical tissue, the general tone of the originally green head and straw becoming progressively golden or silvery and papery in appearance, from above downwards, as the tissues of the floral envelopes and of the culm die. The degree to which ripening can proceed under apparently adverse circumstances is remarkable. In the course of an investigation made by the author green florets of meadow foxtail were placed upon a moist germinator; the kernels were quite green and watery, and in the course of the three weeks normally allowed for a germination test only 7 per cent of them sprouted. The remainder were left on the incubator, and by the end of three months 83 per cent had contrived to ripen and germinate. Had these been harvested and stored dry in the ordinary way there is no question all would have died; presumably the warm moist conditions of the incubator kept them alive long enough to complete the necessary ripening and after-ripening changes, and as each reached germinability it grew.

In clovers, uniformity of ripening is a somewhat more difficult problem than in cereals and grasses. Most of our bulks of clover consist of mixed strains, and an average English summer is second-rate ripening weather, so that the best we can aim at is to harvest when the maximum proportion of the crop is ready. Clover growers commonly walk through the crop and pinch heads here and there between the finger and thumb in order to feel the progress of filling and hardening of the seed, and rub out a few heads in the palm to inspect its colour.

It should be emphasized that while, at least in many in-

stances, some degree of unripeness at the time of cutting is of little moment, and may even be an advantage, it is generally desirable to have seed well ripened before harvest if it is to be stored for any material length of time before use. It is also a matter of common observation that with small legumes, the seed of which must be " drawn " from their capsule as well as threshed from the plant, the seed stores more satisfactorily in the capsule than after drawing. Such seed is often described as *in cosh*—examples are ummilled sainfoin and unmilled common trefoil. Cereals are expected to store better if left on the straw in the stack than if threshed, but this may well be due to better external conditions rather than to factors internal to the plant —evenness of temperature, exclusion of atmospheric moisture, and steady gentle ventilation. Naturally this will only apply if the crop is in good condition when stacked; threshed seed is preferable to a damp stack.

Space forbids any detailed description of harvesting methods. In general, the obvious essentials are: cutting, either by machine or hand; maturing on the " straw," either in " sheaves," " beats," " gleans," or bundles of some sort; and either immediate de-seeding (by hand or mechanical thresher) or further storage in stacks or houses before finally threshing. Hand harvesting is only resorted to in special circumstances nowadays, the cost of labour being prohibitive for most ordinary crops. It may have to be done where ripening is extremely irregular, as with meadow foxtail grass, or where shattering is particularly easy and the seed is relatively expensive, as with parsnip. A point of interest arises in connexion with the latter crop: the juice of the flower stems blisters the skin, and harvesters must be specially protected against it.

In recent years a great advance has been made in harvesting practice by the American introduction of the combined harvester and thresher. The name sufficiently describes this heavy implement—it delivers threshed seed from the standing crop, and it is evident that such a machine can only be used when a crop is ripe. In its present form it is only really suitable for dealing with wide areas, and hence in view of our small fields and our dubious climate we are not in a position to make a very extended use of it. It has, however, found some

favour in the eastern counties of England and some other areas for cereal harvesting purposes.

Seed Storage. In determining the most suitable conditions for the preservation of threshed seed it must be borne in mind that loss of condition or death is most generally the result of interaction of two or three factors, any of which by itself would have to be greatly intensified to cause the same degree of damage. Moderate heat combined with moderate moisture is as harmful as a much higher temperature acting upon dry material. Conversely, ample moisture may be present for very long periods (years) without causing harm if other conditions required for activity (warmth and air) are excluded, as when seeds are buried in the earth. It is probable, too, that *changes* in conditions have an activating and thus deleterious effect. It is well known that certain seeds (e.g. cocksfoot, carrot) germinate better in an incubator if subjected to fluctuation of temperature. Changes in the preliminary stages of germination are closely akin to those causing death in badly stored seed—indeed, they may often be precisely the same. Further, living seed breathes, but breathes very gently, as has been pointed out in an earlier section.

Taking cognizance of these various factors, it will be seen that good storage conditions must provide (*a*) relative coolness, (*b*) relative dryness, (*c*) very gentle ventilation, and (*d*) *uniformity of these three desiderata.* The last is more important than is generally recognized—" thorough ventilation " is commonly advised, and, as usually understood, is not in fact desirable, except in the early days of storage when the drying of the seed is still going on and respiration is still fairly active. The old-fashioned practice of storing apples in a straw stack has much to commend it, and similar means are sometimes successfully adopted for preserving small lots of valuable seed. Such a stack is well adapted to preserve an even temperature, to keep out external moisture, and to allow for the *slow* diafiltration of air. Obviously the straw itself must be dry and sound. For small quantities of seed the common method of storage in paper bags, *not* sealed up, but merely folded over at the mouth, is excellent if the bags are kept at a reasonably low and equable

temperature. For warehouse quantities the seed should be sacked and stacked in tiers—as it usually is. Entirely unventilated containers are dangerous unless the seed is *very* dry at the outset.

Shipping. Special difficulties arise in connexion with transport of seed, especially sea transport where the route lies through tropical waters. This applies particularly to grass seeds, the chaffy envelope of which is well adapted for absorption of moisture from the atmosphere. It is well known that serious loss of viability may occur during transit of grass seeds between Europe and the Antipodes in either direction, and it has been observed that similar damage may be sustained by parcels shipped from Europe to the Pacific coast of America *via Panama*, but does not occur in shipments to New York on the Atlantic coast. The atmosphere immediately over water carries a high degree of humidity, and it has been recorded that the rate of absorption by, for instance, ryegrass seed, is proportional to the *relative humidity* of the atmosphere to which it is exposed. Relative humidity (as opposed to absolute humidity) is the percentage proportion present of the moisture that would be required to saturate the air completely at the existing temperature. Hence the amount of moisture absorbed by seeds depends not upon the actual amount of water vapour present in a unit volume of air (= absolute humidity) but upon the degree of saturation. The graphical record in Fig. 3 shows how faithfully the gain and loss exhibited by ryegrass in the author's experiments conformed to the periodic fluctuations in relative humidity of the atmosphere.

It will be seen that the difference between the lowest figure (recorded on a dry day) and the highest (registered on a wet day) is 7 per cent, equivalent to a change of weight of about 2 lb. per bushel. As might be expected, the husk of grass seed absorbs and exhales more rapidly and more generously than does the kernel, but an imbibed husk acts as a reservoir for the kernel, and unless re-dried will pass on absorbed water slowly to the grain. Suspended over water, ryegrass seed at ordinary laboratory temperatures absorbs moisture until it contains about 25 per cent. During a tropical passage it has not been found to gain so much as this, and, moreover, even 25 per cent

will not of itself cause harm *if the seed is kept cool* and *if the time of exposure* to moist conditions *is not too long*.

The three factors, the interaction of which govern the risk of damage, are temperature, moisture, and time. Any of these may be increased very considerably without harm if the other two are kept low. In practice, as long as steamships are used, the time factor is obviously the least easy to control. Hence it behoves shippers to reduce as far as possible the other two—not a simple matter in either instance. Moisture could be reduced by artificial drying before shipment, but grass seeds that have been artificially dried on a kiln actually re-absorb moisture more readily than undried produce, so that except on a very short voyage it might easily do harm rather than good to dry down beforehand, unless the kilning was carried to such lengths that the seed became " bone dry "—to, say, 2 per cent or less of water—and were then sealed in an air-tight container. This would not be practicable commercially. The author has found normal seed (i.e. containing some 12–13 per cent of water) shipped to San Francisco in air-tight containers to suffer much greater loss in germination capacity than the same seed shipped in ordinary double sacks.

In regard to temperature, the trader is handicapped by inability always to supervise stowage and by the impossibility of avoiding tropical sea routes to certain destinations, or the added expense of avoiding them where avoidance is geographically possible. The highest temperature recorded by the author (in a parcel of seed shipped from Belfast to the west coast of America) was only 35° C. (= 95° F.), but lower temperatures than this have proved very damaging, on occasion, when combined with moist atmosphere for a period of several days. In all these circumstances the refrigerator ship suggests itself as the most satisfactory solution to the problem. This may be so, for experimental trials with artificial cooling have given satisfactory results, but refrigeration of a ship's hold is an expensive matter. In commercial practice grass seed is generally shipped in double hessian, linen, or cotton sacks (commonly each containing 2 or 1 cwt.) packed closely in a flat tier in the hold, away from engine-room bulkheads, and covered with a spread tarpaulin.

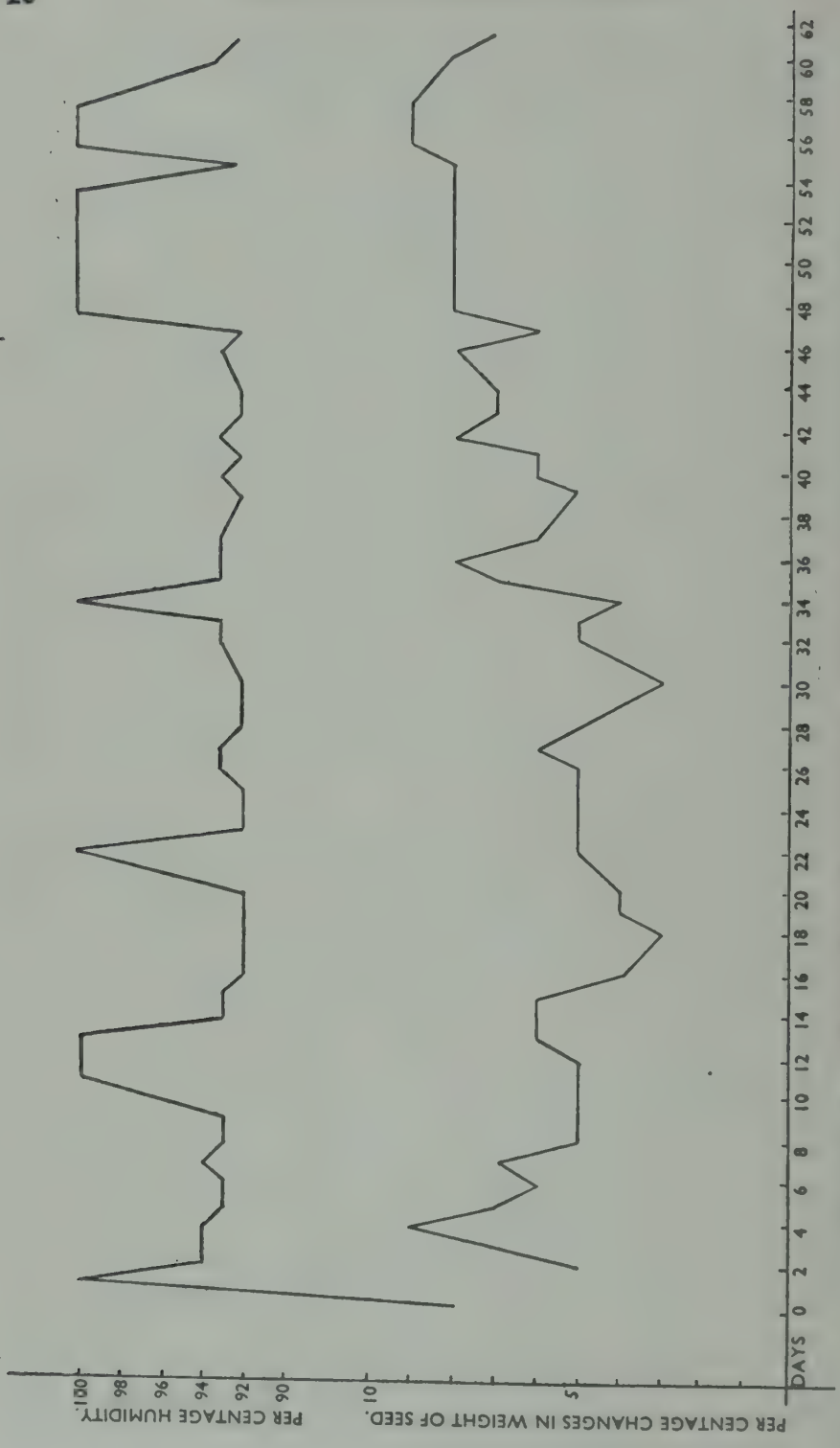


FIG. 3.—Graph showing response in perennial ryegrass to changes in atmospheric humidity.

It is sometimes found that seed shipped from Europe to Australia or New Zealand shows a lower weight per bushel upon arrival than when despatched. Investigation indicates that this is not due to loss of water and must mean that fewer seeds will go into the bushel measure—that is, the individual seed occupies more space than it did originally. This is explained by the slight forcing apart of the valves of the husk under the influence of absorbed water during the tropical part of the voyage, and inability of the valves to close quite tightly again when that water is lost in the drier atmosphere of the final temperate stage of the journey, by reason of the tiny teeth borne on their opposed edges. A purchaser sometimes makes a complaint on this score, but it is rebutted by the argument that he receives the *number of seeds* he pays for; the fact that they are individually slightly larger does no harm.

It must not be supposed that damage of the kind described is the usual thing in sea-borne seed. Far from it; usually, even in tropical voyages, no harm occurs. The matter is here discussed on account of its interest, not because of its frequency.

Seed Cleaning. In order to separate sand from sugar the analyst seizes upon the physical characteristic in which the two most markedly differ; he washes out the sugar by dissolving it in water. On the same principle, to clean and purify a parcel of threshed seeds the machiner makes use of the characters in which the impurities differ most widely from the " pure seed " (i.e. the species to be isolated). Thus the action of seed-cleaning machinery depends upon the relative (*a*) size, (*b*) weight, (*c*) specific gravity (a function of *a* and *b*), (*d*) roughness or smoothness, or (*e*) shape of the species in the original bulk (Fig. 4).

The hand sieve and the numerous machines making use of sieves, including the thresher itself, depend of course upon the first-named factor. Sieving in one form or another is the most generally useful and the most widely used cleaning method. Obviously, large impurities may be separated from small seed, or small impurities from large seed, by an appropriate sieve.

The indented cylinder machine employs the size factor in another way. Essentially it consists of a hollow metal cylinder having a

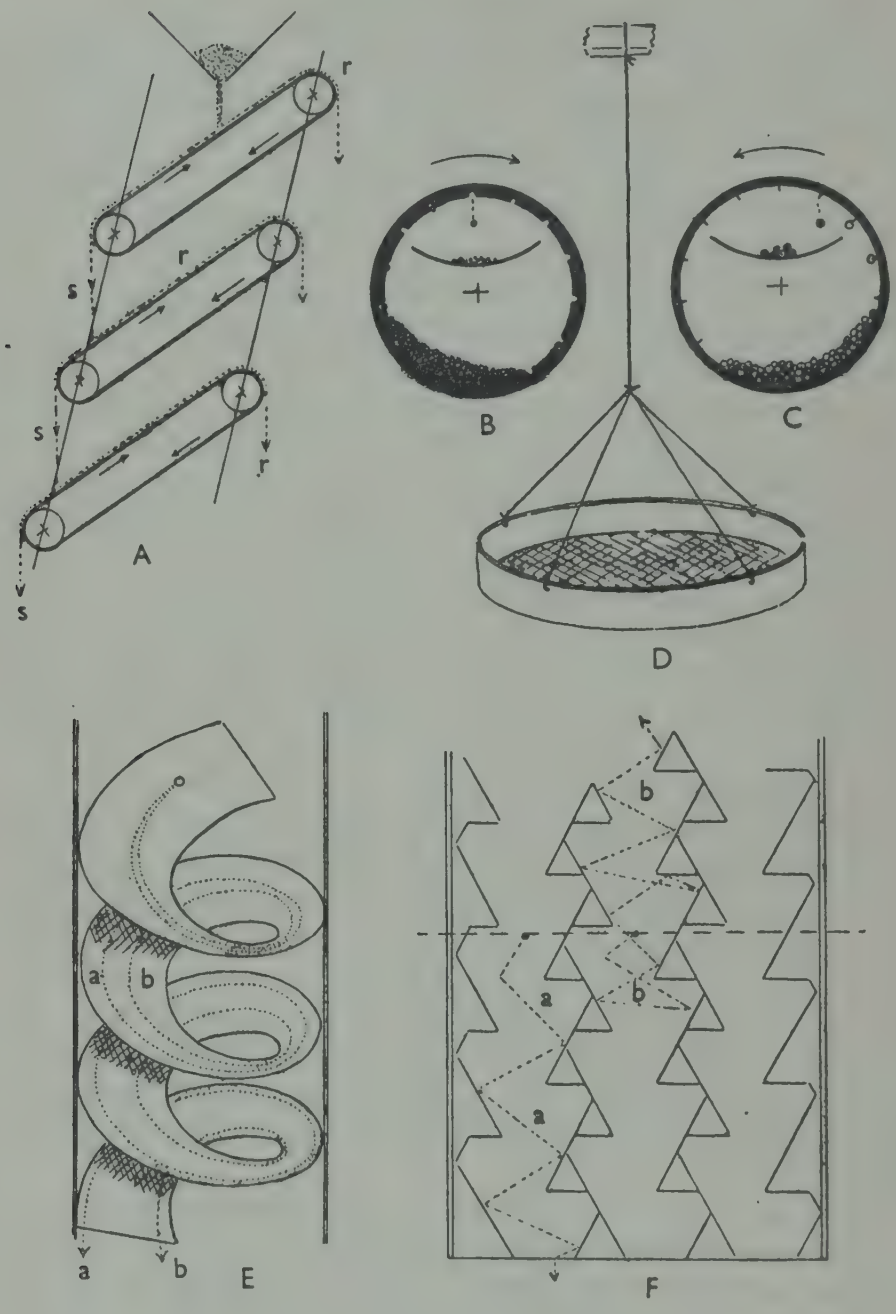


FIG. 4.—Diagrams of machine principles (*not to scale*).

A—velvet sleeve; B—indented cylinder; C—pegged cylinder; D—suspended riddle; E—spiral chute; F—" dog-leg " oscillator.

The dotted lines show course of seed—*a*, heavy; *b*, light; *s*, smooth; *r*, rough.

smooth trough suspended lengthwise inside it, of slightly less width than the internal diameter of the cylinder, and placed above the centre line of the latter. The inside face of the cylinder is pitted all over with cup-like depressions. The whole assembly is tilted longitudinally and seed is fed in at the upper end of the cylinder, which slowly revolves. A cylinder is chosen in which the pits are slightly smaller than will accommodate the seed to be cleaned; impurities of smaller sizes fall into the pits and are carried upwards by the revolution of the cylinder until they approach the top position, when they fall out (the pits being now inverted) and are caught by the suspended trough. The pure seed merely slides slowly down the cylinder and is delivered at the lower end. Ribgrass (*Plantago lanceolata*) is extracted from red clover by such a " rib cylinder " machine.

Weight and specific gravity give effect to *wind-blast* and *centrifugal* machines. There is a great variety of wind-blast machines ranging from a sheet of paper to gargantuan monsters occupying a warehouse floor. The sheet of paper is by no means to be despised. It is a very useful instrument for " dressing up " small bulks of seed. The paper is held in both hands, the edge nearer the user being crushed so as to give a truncated fan shape to the sheet, the ends of which are held higher than the middle so as to give a shallow cupping effect. A handful of seed at a time is put on the paper, which is then given a gentle combined tossing and flapping motion: the whole sheet is moved up and down, but the front edge more violently than the back edge. The effect is to keep the seed tossing an inch or two in the air over the centre of the paper while light chaffy and dusty material is withdrawn from it by the forward air current set up by the flapping front edge. Knack, acquired by practice, is needed in this operation. A facile worker can by its means achieve a surprisingly sharp division between chaff and seed; so much so that the process in a modified form is employed in some State Seed-Testing Stations as a preliminary means of separating husk from " full " seed in purity analyses of grass seed samples. A shallow wooden tray is used, having sloping sides and ends, and known by its original Danish name of *drøfter truge* (fanning dish). It resembles in

general appearance a rectangular " butchers' tray " without the projections. It is gripped lightly at two opposite corners and swung in the fingers so as to toss the seed as before, the draught being produced by the forward free corner of the tray, over which the lighter particles escape.

On a larger scale the same principle has long been in farm use and may still occasionally be seen employed in connexion with corn threshed by flail. A cup-shaped rush " wisket " (basket) with grips not quite opposite is partially filled with a few shovelfuls of grain and chaff, lifted by the grips, the wider side away from the worker, and heaved and flapped by the arms and knees in concert. Millet's painting, *Le Vannuer*, depicts a husbandman thus engaged.

From these elementary implements it is a small step to the *winnowing machine* in which the air blast is provided by a rotary fan, and the combination of this with sieves is a further fairly obvious advance. This association is to be seen in the thresher, in the modern farm winnower, and on an expanded scale in the trade warehouse machines.

Centrifugal machines are fewer. A hand-operated example useful for small bulks consists of a shallow flat-bottomed circular dish or sieve suspended by a central cord to which a " swilling " motion is given by slightly rocking and simultaneously swinging in a circular orbit. If the instrument is partially filled with a smooth seed such as flax, the swilling motion is imparted to the seed, with the result that the smooth and heavy flax tends to swirl to the outside of the circle and lighter impurities to collect in the centre, whence they can be picked out. An automatic centrifuge requiring no power, but useful for a limited range of jobs, consists of a spirally coiled sheet of smooth metal enclosed by a cylinder in the same way that the outer wall encloses a spiral newel stair. Seed is fed on to this from a hopper at the top. As it slides down the steep spiral it must travel round and round the cylinder and naturally the heavy material crowds to the outside and the lighter accumulates towards the centre. A division at the bottom of the spiral then directs light and heavy into separate receiving hoppers. This implement serves well for separating relatively simple mixtures such as peas and oats.

A recently introduced machine, capable of very fine and accurate separations, variable to suit a wide range of subjects, makes use of the centrifugal principle in a new way and enormously augments its possibilities. This machine is power-driven, and in essence consists of a tilted table divided longitudinally by a number of dog-leg shaped partition walls a few inches high standing up from its surface. Seed is fed in a very slow stream on to the " table " which is oscillated from side to side. The amount of tilt and speed of oscillation can be regulated. The seed slides very slowly down the slope of the table in longitudinal streams between the upstanding partitions, but in doing so is shaken from side to side by the motion of the machine so that it strikes first the dog-leg on one side and then that on the other of its path. If a seed is struck by the upward tending face of a dog-leg it is thrown thereby in a slightly upward direction (against the slope of the table). If it is heavy enough it will overcome this upward thrust before it strikes the opposite dog-leg and will miss the upward face of the latter and hence work its way lower down the table, but a light seed will fail to do so and will again be thrown upwards. The total effect therefore is that light seeds tend very gradually to work their way *up* the sliping table, and heavier seeds to filter slowly *down.* Heavy and light fractions of any mixture are thus delivered at the bottom and top of the table respectively, and so accurately can the oscillation, the rate of feed, and the tilt be adjusted that astonishingly fine separations can be made even between constituents of almost the same specific gravity. The diagram (Fig. 4) will make the action of this machine clear.

A method occasionally employed to separate mixtures by means of specific gravity variations is that of *flotation.* Theoretically it should be possible by this means to make the finest possible separations. In practice the difficulty is that the range of variation in specific gravity among individual grains of a sample may overlap the range of variation covered by the impurity. In such an event the most careful adjustment of density of the flotation medium will evidently fail to give perfect separation. The method has been tried for a number of difficult cases, such as extraction of dodder (*Cuscuta*) from clover seed, but it has not become common practice. It is more effective in

instances where the discrepancy in specific gravity is greater, as with " bunt balls " in wheat. These are the skins of wheat grains packed with a sooty mass of spores of the bunt fungus in place of flour. They are approximately the size of the normal grain, and while not sufficiently light to blow out satisfactorily under a wind blast, are light enough to float in a salt solution of such strength that normal wheat just sinks in it. An infected sample being agitated in such a solution, the bunt balls float to the surface, and can be skimmed off. The immersion does not injure the grain if it is brief and if followed by washing and drying.

Roughness of seed coat is made use of in two principal ways. A rough seed will not roll or slide down a sloping rough surface so easily as a smooth seed. A very rough seed may refuse to move at all on a suitably rough surface. Degrees of roughness in the seed may be met by choice of suitable grades of roughness in the surface and by the pitch of the slope. Use has been made of this principle in several machines, plush or velvet surfaces being usually employed, and the implement at present in almost universal use for cleaning small clover seed is an excellent example. In this machine the seed is caused to pour over a series of velvet sleeves carried upon pairs of rollers and set like a series of sloping steps in a tilted rectangular frame. The rollers are driven to rotate the sleeves in an upward direction. The machine is set so that this rotation just fails to prevent the clover seed sliding down, but does arrest rough-skinned weed seeds or other rough impurities. The latter cling to the velvet, are carried upwards and discarded, while the purified clover collects " at the bottom of the stairs." This has proved an exceedingly efficient device.

An extremely ingenious *magnetic machine*, upon a principle devised in a moment of inspiration by a young lady then quite strange to the seed business, is employed for the extraction of dodder seed from clover. The large-seeded variety of dodder is almost exactly the same weight and size as red clover and nearly the same shape—but it has a *very slightly* roughened skin while that of red clover is smooth and polished. In order to extract dodder from a bulk of clover seed the whole is sprinkled with a fine magnetic powder and subsequently shaken free of

it again. The polished surface of the clover seed does not hold the powder, but the dodder is just sufficiently rough for some of the tiny grains to remain attached. The bulk then being passed in a slow stream under a magnet, all particles which have retained any of the powder adhere to the latter while the pure clover seed, carrying no powder and being unaffected, passes on. It will be seen that although this process is primarily directed to the extraction of dodder, it will automatically withdraw any impurity capable of retaining the powder and light enough to be lifted by the magnet, including cracked or broken clover seeds, the powder sticking in the cracks or on the rough fractured surface. The introduction of this machine (about 1922) proved a highly successful method of combating one of the worst bugbears of the clover seed growers in warm countries where the parasite is common in clover crops, efficient extraction having up to then been impracticable, and the presence of the seed in the produce a grave bar to export sales.

Shape, although often one of the most obvious differences between species, is a difficult characteristic to impress into the service of the cleaner: it is not easy to design mechanical appliances that will sense shape! It has, however, been done: there has recently been introduced a machine that discriminates between weevilled peas and sound peas, and extracts the former from a threshed bulk. The larva of the weevil feeds by tunnelling inside the flesh of the pea, and when the insect leaves the seed the round hole through which it has emerged, opening into a tunnel, is left. Damage of this kind is commonly a very serious drawback in seed peas, especially those from certain European countries largely exporting to the United Kingdom. The tunnelled individuals are now removed by a machine fashioned somewhat in the manner of the " indented cylinder " (p. 27), but having the inside of the drum furnished with numerous short pegs instead of depressions. When the peas are rolled round and round in such a drum, sooner or later the weevil hole in a damaged individual is caught by a peg. The injured pea is thus " hung " on the peg until the revolution of the cylinder brings it to the top, when it falls off and is discharged as " impurity." Sound peas cannot of course hang themselves on pegs.

The " long mesh " sieve also depends for its action upon the shape of the particles laid upon it. Sieves are generally " round mesh " or " long mesh." (Square mesh is very unusual.) These terms explain themselves. The long-mesh instrument is built of wires or bars laid parallel at precise distances apart and bound transversely by similar or thicker rods spaced more widely apart. Alternatively they may be of sheet metal through which narrow rectangular holes are milled or punched. Such sieves serve to separate species that are approximately similar in volume and weight but one of which is elongated in form and the other more nearly globular. For example, by careful manipulation, a long mesh of suitable dimensions will achieve the difficult separation of shelled soft cranesbill (p. 105) from white clover.

Disposal of Cleanings. It is often difficult for the grower to realize how much impurity his threshed and perhaps winnowed sample of seed contains, particularly the grower of small (grass and clover) seeds. Largely for this reason, no doubt, he not infrequently sows his own home-produced seed without subjecting it to commercial cleaning. It is by no means easy for an experienced seedsman or analyst to estimate by eye—even approximately—the proportion of chaff and weed seeds in a sample. Chaff of course does no harm if you choose to sow it: weed seeds do. Unfortunately the seeds of weeds infesting a given crop have a habit of superficially resembling those of the crop. Separated, the two are commonly distinct enough in appearance, but the eye, inspecting a mass of the two mixed together, is so " hypnotized " by the multitudinous number of the crop seeds that it easily fails to detect what may be a very material percentage of the weed. Only in very rare instances is it good practice to sow uncleaned (i.e. not professionally cleaned) seed. It may be acceptable for such special purposes as clothing a new embankment or renovating certain types of poor mountain pasture, but it should not be done on decent agricultural land.

The nature of the crop and, dependent thereupon, the style in which it is grown and harvested, largely determine the kind and amount of impurity the threshed sample contains; the

nature of the crop and weed seeds respectively are the chief factors controlling difficulty of cleaning. One would not expect much impurity other than straw and chaff in, say, turnip seed grown from a crop of hand-planted " bulbs," in wide drills, kept clean by cultivation. On the other hand, there is scarcely any limit to the weeds that *may* intrude in a crop of grass, sown broadcast, perhaps on foul land and of necessity uncultivated. Roots and vegetables are in the main relatively easy to clean, cereals fairly so, clovers relatively difficult, and grasses, broadly speaking, probably the most difficult on account of their irregular shapes and frequent " stickiness " owing to awns and hairs.

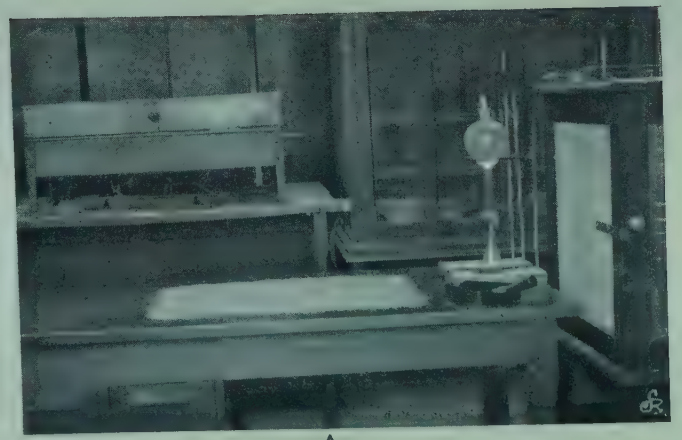
Most countries nowadays have laws and regulations governing the importation of, trading in, and sowing of agricultural and horticultural seed. Hence the avenues for disposal of " cleanings " are few and becoming fewer. On the whole this is desirable. If a wholesale cleaner cannot dispose of his cleanings at any price, clearly it will affect the price at which he can sell his clean product. Most seeds, however, are so cheap in view of the immense numbers in a small weight that the use of poor quality seed on the score of expense is not justified, and any system that tends to its discouragement is, to that extent, good. There is a certain amount of sale for some grades of cleanings for the manufacture of feeding stuffs such as poultry meals. Sometimes it happens (quite rationally) that a common weed of one country ranks as a useful species in another. There is, for instance, a certain amount of sale abroad for Yorkshire fog (*Holcus lanatus*) which is actually classed as an " injurious " weed by English seed regulations. Sometimes there is nothing to be done with cleanings but burn them.

A point often lost sight of is that, in spite of the skill of experienced cleaners, and of the ingenuity and efficiency of modern machinery, weeds cannot be cleaned out of a bulk of seed without some loss of the crop seed accompanying the extraction. This explains (in conjunction with the difficulty of seeing the impurities) why a crop often loses more weight in cleaning than the grower thinks it should. For example, with ryegrass the total amount the machiner is *obliged* to remove in order to produce a merchantable sample may

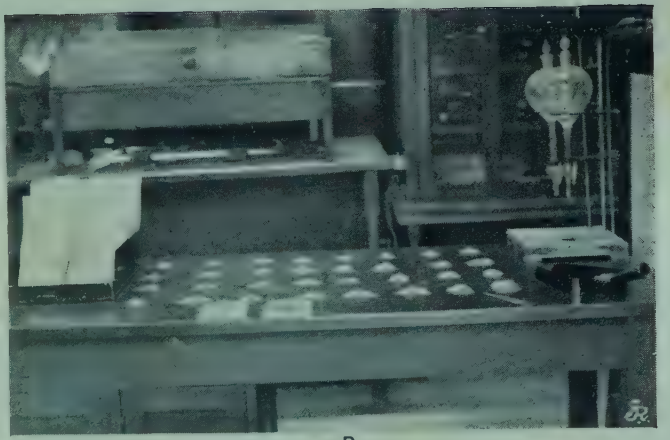
vary between 15 and 25 per cent, or even more in a difficult season.

United Kingdom Seed Supplies. HOME-GROWN SUPPLY. The longer a crop species has been in cultivation the more numerous become its varieties. This is natural enough; the reasons are clear. Less obvious are some of the corollaries, amongst which is the fact that a country commonly produces its own supply of seed of the older crops and imports supplies of those more recently domesticated. This applies particularly to countries like our own, not specially suited for seed ripening. The greater the choice of varieties the greater is the tendency for these to segregate into groups particularly successful in individual world areas, and the greater is the difficulty of obtaining seed of a given type outside its adopted area. Hence home production. Cereals have been in cultivation for thousands of years and varieties are legion. So we find some wheats particularly suitable in, say, the United States of America, but others in Great Britain, and purchase of seed from one area by the other would simply mean buying unsuitable varieties. With a " younger " crop, however, such as red clover, where varieties have as yet only been selected to a relatively small extent, the type is more generally uniform (even though the " uniformity " may be due to heterogeneity of stocks) so that we can grow successfully red clover purchased from France, America, Sweden, or New Zealand. (Exceptions to any such broad principle are of course easily thought of and are nowadays being rapidly increased by deliberate organization.)

There is an increasing tendency to import seed from an area of relatively severe conditions to one of softer climate, and a marked one to reduce by actual legislation the opposite exchange. Witness the several countries that have in recent years instituted regulations requiring staining of seed imported from southerly latitudes, and, in some instances, prohibited importation of certain species altogether. In the United Kingdom, then, we produce much of our own supply of cereal seeds; most of our own seed of the " older " grasses (rye-grasses), but less of other grass species and of some practically

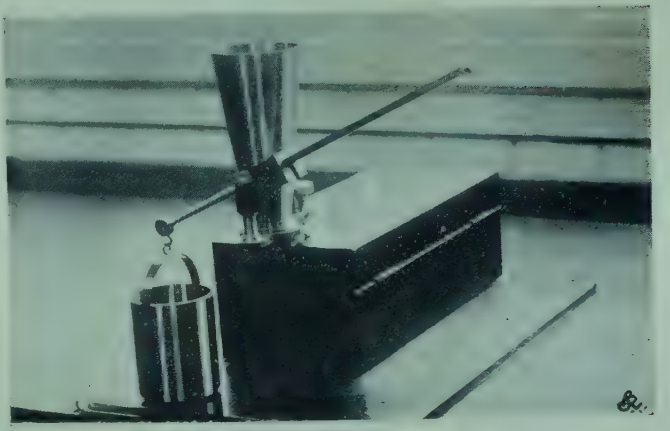


A



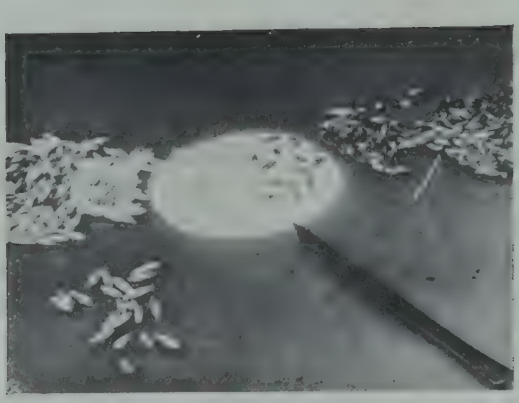
B

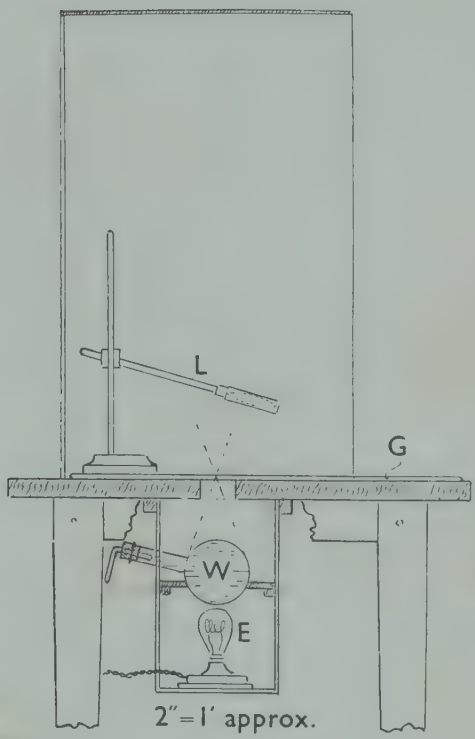
C



D

FIG. 5.—A—Seed poured for sampling. B—Division of heap in sampling. C—Dodder machine. D—Chondrometer.





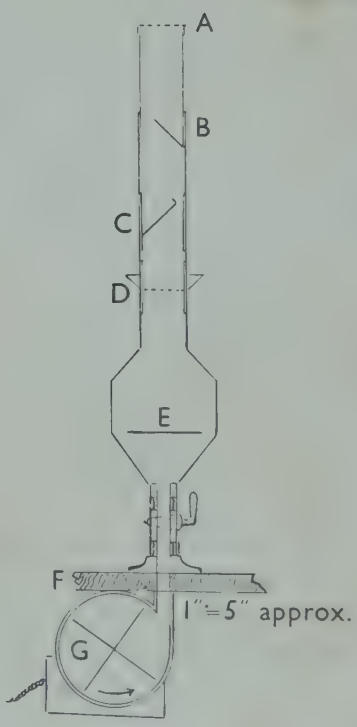


FIG. 6.—Above: *Left*—Seed on the diaphanoscope; *Right*—Aspirator.

Below: *Left*—Section of diaphanoscope: L—adjustable lens; G—glass plate; W—round flask of water; E—100-Watt electric bulb. *Right*—Section of aspirator: A—gauze cap; B, C, E—baffle plates; D—gauze diaphragm; F—table; G—fan.

none; a fair proportion of our clovers and of certain root crops; relatively little of other root crops and of vegetables.

Grasses. Our chief home-produced species is perennial ryegrass, and its variety Italian. These are grown in Northern Ireland, Scotland, and the Fen country. The first-named area harvests some 20,000 tons in an average year and is the world's chief ryegrass-producing centre; the second about one-third of this amount, chiefly in Ayrshire and Stirlingshire; while relatively very small quantities (of Italian) are grown in Cambridgeshire (Isle of Ely). During the past few years there has also been grown a considerable acreage of the special strains of perennial ryegrass that originated from the Welsh Plant-Breeding Station (see p. 43). One or two counties in the Irish Free State are within the " grass seed " area of Ireland, but inter-trade with these counties has latterly been severely reduced.

Perennial ryegrass is sown down in a mixture of grasses and clovers, and after harvesting once for seed the ley remains two or three years as pasture. Italian ryegrass is sown alone and ploughed up after one seed crop has been taken. Average crops are, of perennial about 5 to 6 cwt. and of Italian about 7 cwt. per acre.

Second in importance is timothy. Scotland is responsible for the annual production of some 100 tons of this, chiefly on the carse lands of Stirlingshire, with some from Ayr. Timothy does not mature a material seed crop in its first year, and ryegrass is sown with it to provide hay. Heavily manured, it is subsequently harvested for seed, with intervals for rest, over a number of years. Average Scottish crops thresh from 3–5 cwt. per acre. Latterly appreciable quantities of seed have also been produced in this country from Aberystwyth-developed strains (see p. 43).

The next most prominent species is crested dogstail, which varies in amount very widely from year to year. The average home crop is in the neighbourhood of 1,000 tons. Almost all of this is grown in a restricted area in County Down and County Antrim, where it is grown in the manner of a cereal, without admixture, and harvested twice, the second year's crop being the heavier. A little is harvested as an " impurity," separated from pasture crops of wild white clover in south-east

England. From the specially grown seed crop 4–5 cwt. of seed per acre are harvested.

Before the recent war home supplies of cocksfoot supplied only a small fraction of our requirements. The war years, however, have seen a very remarkable increase in the quantities produced in this country, as will be noted from the table given on p. 43. In the main this seed has been obtained from special strains that were introduced by the Welsh Plant-Breeding Station. Further, the quality of the seed produced in respect to purity and germination has reached extremely high standards and reflects the greatest credit upon all concerned in its production. Very small amounts of fescues and rough-stalked meadow grass are also harvested in some seasons in the southern and south-central counties of England, but the contribution to supplies of these is practically negligible.

Clovers. The main clover-seed-growing area of Great Britain lies to the south of a line drawn from Bristol to the Wash. Red and white clovers are largely produced, alsike less. Of red clover, two main types, under a variety of names, are used—the common early-flowering, double-cut " broad " red and late-flowering or single-cut. There are numerous locally recognized " strains " or varieties, but distinctions between these are nebulous. In certain counties, such as Essex, where red clover growing is heavily concentrated, clover sickness is apt to be a troublesome handicap. It is usually the result of infestation of the land with the fungus *Sclerotinia trifoliorum*, or sometimes with a parasitic eelworm. The crop cannot be grown on land thoroughly " sick," but the late-flowering type is found distinctly more resistant to attack than the double-cut broad red. Red clover is sown alone when required for seed, and as regards broad red the *second* crop of flowers—the aftermath—is used. In actual number of flowers carried the first growth would be more productive, but red clover is self-sterile and the deep narrow tubular shape of the flower necessitates pollination by a long-tongued insect. In practice the active agent is a humble bee, which is not abroad at the flowering season of the first growth of broad red, so that very few flowers are fertilized and consequently very little seed is produced. With a single-cut type this practice obviously cannot be adopted, since

no material amount of aftermath is produced, but the main crop is sufficiently later than that of broad red to " catch " the humble bees, at least to an extent permitting the harvesting of a reasonable crop. Red clover is a heavy and a sappy crop, not easy to cure into hay except under the finest weather. Small stacks are used and are commonly ventilated by the insertion of bundles of brushwood or the formation of " chimneys " (upright hollow shafts) by building the hay around stuffed sacks, which are drawn up continually as the level of the stack rises. An average crop of red clover in England yields some 4 bushels (say, 260 lbs.) of seed.

White Clovers are also of two types, cultivated or Dutch and wild or indigenous. These are both mixtures of strains and the difference between them lies in the proportion of long-lived individuals, which is very high in the wild type and low in the cultivated. The description " wild " has become a trade term and does not imply " unsown "—both types are in fact cultivated, but while Dutch is grown alone on arable ground, " wild " is harvested from pastures that have been sown down for a term of years with a mixture of " permanent " grasses and clover. Some of the finest of these pastures are remarkable for the simplicity of their composition, consisting almost entirely of white clover, perennial ryegrass, and crested dogstail. The harvesting of pastures of wild white clover is a matter calling for care and skill. In Kent, where the industry first developed about the beginning of the present century, the rainfall is low and the plants are often of extremely low stature. They must be cut very closely and even then the flower-heads are sometimes so short-stalked that they cannot be raked by ordinary implements and must be collected on sheets of sacking dragged on the ground behind the cutter bar of the mower. A crop of this sort consists almost entirely of flower-heads and takes relatively little curing before it appears dry, but the heads turn brown and seemingly dry before the contained pods and seeds are in fact mature, and precautions against heating are desirable when stacking.

Wild white clover is remarkably catholic in its taste in soils and will succeed under the greatest diversity of conditions. The two chief centres of seed production are, however, relatively

small areas (*a*) in Kent around the Bethersden district, and (*b*) on the Cotswolds. Small quantities are harvested in a rather desultory manner elsewhere. The crop does exceedingly well in the east of County Down and in favourable seasons profitable crops have been seeded there; but the rainfall is much higher than in the east and south of England and the grasses are apt to grow too luxuriantly and swamp the seed-bearing clover heads. An average pasture crop of seed is about 50 lb. per acre. The seed sold as "wild white once grown" is the produce of a crop sown down on arable ground with wild white seed from an old pasture. It is thus "cultivated" to the extent of one generation, but this is not sufficient to make any detectable difference in the agricultural quality of the strain. It has in practice given results quite on a par with those obtained from true old pasture seed, and of course larger yields of seed can be obtained from an acre under arable conditions than can be expected from a pasture. England produces practically all the wild white, and a large proportion of the Dutch white seed used in the United Kingdom. Essex, Suffolk, Sussex, and Hampshire are the most prominent counties in the production of Dutch clover. In recent years the Aberystwyth strain of white clover, S.100, has to a very considerable extent replaced ordinary Dutch white. White clover enjoys the advantage of being much less susceptible to attack by the clover sickness organisms, and may be substituted for red clover when there is a danger of failure from the latter. Dutch white is sown alone when intended for seed, and a sowing of about 7 lb. per acre will yield a harvest in the neighbourhood of 200–250 lb. As with red clovers, locally reputed stocks of white clover are common, the same strain having been retained on the same farm for many years.

Official schemes for the certification of seed from genuine old pastures are in operation in England and in some other countries (see also p. 43).

Alsike has never become a popular seed crop in the British Isles. A few crops are grown in East Anglia and give yields of some 4 bushels (say, 260 lb.) per acre, but no growers make a regular practice of producing it. It is very resistant to clover sickness and there seems no adequate reason why it should not be more largely home produced. It does not produce an aftermath crop of flowers, so that first growth must be harvested.

Apart from this the general treatment is much as for red clover.

Crimson Clover is an annual crop, of which we produce the major part of our seed requirements; the remainder has usually been received from France. It is a rather difficult crop in that the seed shatters easily; it is very hairy and holds water from rain or dew; and the seed itself when ripe and dry is brittle and easily cracked or broken by careless handling.

Lucerne is grown on a small scale only, the bulk of the seed used being imported. Our seed formerly came mainly from France, but latterly Canada and the United States have been our suppliers. The major difficulty in producing lucerne is to keep the crop clean in the early stages; when young it does not compete at all well with weeds. Until recently it has been believed that it could not succeed in the Midlands or west of Great Britain, but it is now clear that if the seed is inoculated with a culture of root-nodule-forming bacteria (*B. radicicola*) of the correct strain it is not adversely affected by longitude within the limits of the United Kingdom.

Sainfoin, *Trefoil*, and *Kidney Vetch* are chalk-loving species, and are therefore to be found in cultivation chiefly in the calcic areas of East Anglia, Northern Hampshire, and the Oolite districts of the Cotswolds. The United Kingdom produces the main part of her requirements of seed of the first two species, but imports more of the kidney vetch. Two distinct types of common sainfoin have developed as a result of differing seed production practice—a long-lived type in Hampshire where the crop is not seeded until it is some half-dozen years old, and short-lived plants have therefore died out, and a short-lived strain in East Anglia where it is harvested at a much younger stage (often at only two years old).

Root Crop Seeds. Seeds of cruciferous species (cabbage family) are produced in major quantities in East Anglia. The chief sorts are: turnip (common and Swedish), cabbage and kale varieties, rapes and mustards. The two last-named are annuals, while the others are generally grown as biennials, but can be made to behave as annuals if sown late in the year. Turnips and swedes, developing " bulbous " roots if sown in the spring, can be lifted in autumn, stored over winter, and again planted

out in the following spring when they produce tall flowering stems, fruit, and seeds, largely at the expense of the stored food material in the bulb. This is the common method of treatment and growers regard it as an advantageous method in that it permits them to pick over the roots before replanting and use only those that are sound, well-shaped, and of the type they seek to perpetuate. The reality of the advantage of this is dubious; the " characters " carried by the seed depend on other factors besides the quality of the immediate female parent.

Alternatively turnips may be sown at the end of the summer, when they make small plants, resembling rape, in the autumn. These remain in the ground over winter and next year " bolt " to seed without " bulbing." There is no difference in the genetical constitution, and hence none in the quality or type, of crops grown from seed raised by these respective methods. The difference in the behaviour of the crop according to season of sowing is probably due chiefly to the difference in length of day experienced by the plants at corresponding stages under the two systems. This influence is bound up, too, with the " vernalization " principle—evidently under the existing lighting conditions the capacity to fruit can develop while vegetative bulb formation is arrested during the winter.

Perhaps the most prominent difficulty the cruciferous seed grower has to face is the noteable ease with which the species inter-cross. Such hybridization is often disastrous, as when a turnip variety is crossed with rape, the resulting hybrid being a useless " bastard " with a small, fibrous, woody bulb. The only effective means of preventing inter-crossing is to keep seed crops of different varieties or species isolated from each other, and contracts for the growing of these types for seed commonly provide for the maintenance of stated distances between crops.

In general features the practice in producing seed of mangolds and of beet is similar to that in vogue for turnip.

Vegetables are also seeded to a small extent in East Anglia, but in the main we do not produce our own seed of these.

Flax. Formerly the seed was mainly imported, although a small amount was grown, especially of prized varieties, but the main bulk used was either " grown on " from small bulks sent out from home or consisted of foreign-grown produce imported

by ordinary purchase. First-class fibre and first-class ripe seed may not be produced from the same crop. Our climate—particularly that of Ireland—permits us to produce first-class fibre, but seed production is apt to be somewhat more risky. Nevertheless, during the past decade this country has produced large quantities of excellent seed, and it will be interesting to see to what extent the production of seed will survive when world conditions become more normal. It is to be hoped, however, that we may continue to produce a greater portion of our own requirements than we did in the past. The flax plant is a short-lived annual, the individual blossoms of which only persist one day (hence the rather disappointing appearance of a field of " the fairy flax " in bloom), and bears round capsules each containing several seeds. Blossom colour is either blue or white according to variety.

INDIGENOUS STRAINS. Wild white clover has been harvested in varying quantities in the United Kingdom since about 1880. Its immense value became widely known in the second decade of the twentieth century. Strangely enough the value of similar strains of grasses has only come into prominence in more recent years. Special strains of ryegrass, cocksfoot, and timothy are now available, and are being produced upon a considerable scale in England and Wales. Since the source of these strains was the Welsh Plant-Breeding Station they are commonly known as Aberystwyth strains. Some idea of the rapidity with which the production of these strains has been expanded is conveyed by the table, showing the acreage devoted to the six best-known strains in 1941 and 1946.[1]

		1941	1946
		acres	*acres*
Pasture-type Perennial Ryegrass .	S. 23	533	6,266
Pasture-hay-type , ,, .	S. 101	92	3,349
Pasture-type Cocksfoot . .	S. 143	172	3,566
Pasture-hay-type Cocksfoot . .	S. 26	226	3,301
Hay-type Cocksfoot . . .	S. 37	53	2,244
Pasture Hay-type Timothy . .	S. 48	7	1,128

Although grown to a lesser extent other strains are also available.

[1] See Seed Production Committee Report, National Institute of Agricultural Botany, 1946.

Certification. Seed carrying an official certificate of trueness to type, produced from crops grown under Government supervision, is available in certain Dominions and some foreign countries. In England an official certification scheme has been in operation for many years in connexion with wild white clover seed production. During the war years schemes for the inspection of approved local strains of herbage seeds have been developed and are now in existence in a considerable number of counties.

OVERSEAS SOURCES OF SUPPLIES. Among imported agricultural species, clovers and grasses are the most prominent. Before the last war red clover came to us from Chile, France, Italy, the United States, Poland, and New Zealand. In recent years, however, our supplies have been drawn almost entirely from Canada, the United States, and New Zealand. Stocks from Southern Europe and South America are generally larger seeded and produce rather short-lived soft crops. They are also apt to contain dodder. For some time there has been a tendency to stress the use of seed from more northern latitudes, and certain countries now discourage imports from warm climates. *Alsike clover* originated as a domestic crop in Sweden. Our seed is mainly of Canadian origin. *White clover* was formerly imported from Central Europe, Canada, and New Zealand. Supplies from Europe are no longer available. *Wild white clover* is obtainable from New Zealand, but stocks from the Dominion are apt to be variable. Produce carrying an official certificate as to *strain* is, however, available.

The importation of the larger grass seeds fluctuates very much from season to season, according to the available supplies from home production. *Perennial ryegrass* may be had from Denmark and also from New Zealand, but here again stocks from the Dominion are apt to be variable and only officially certified strains are desirable for use here. *Argentine ryegrass* and *North American domestic ryegrass* are very short-lived types entirely unsuitable for British use. *Cynosurus echinatus*, sometimes met with under the description of "Chilean" ryegrass, is not ryegrass at all and quite useless to us. *Italian ryegrass* was formerly purchased from France and Denmark. Supplies from Denmark are becoming available once more. *Cocksfoot* reaches us

from New Zealand and exports from Denmark have now been resumed. *Meadow fescue* is chiefly obtained from the United States and Denmark. Our imported supplies of *Crested dogstail* come from New Zealand. *Timothy* we import from Canada and the United States. Of the species often referred to in the trade as " natural grasses," *rough-stalked meadow-grass* (*Poa trivialis*) is of Danish origin, and *smooth-stalked meadow-grass* (*Poa pratensis*) is supplied entirely by the United States. *Chewings fescue* (*Festuca rubra* v. *fallax*) comes to us from New Zealand. Supplies of other small fescues which came entirely from Europe have ceased. Imports of *Meadow foxtail*, which came from Finland, have also stopped. No doubt, however, when European trading conditions become normal such seeds will again be procurable.

A good deal of prominence during the past two decades has been enjoyed by species of *Agrostis* under the familar name of *bent*. This genus has come very much to the fore for lawn and sports ground purposes. Under our conditions the best species is *Agrostis tenuis*, the so-called New Zealand " brown top." In pre-war days we also imported small quantities of German mixed bent, but these have now ceased. Another species, the well-known fiorin or " red top " (*Agrostis stolonifera*), is supplied to us by the United States.

Chapter Three

Seed Testing

Purpose. There are two plausible views of the real purpose of seed testing. One school of opinion holds that the primary purpose is to assess the crop-producing potentiality of the seed; the other asserts that it is a conventional method of grading for commercial purposes. The fact is that seed-testing stations are called upon to do both these things, and it is idle to argue the question, "which is their primary *raison d'être*?" From the historical point of view, information for the husbandman was no doubt the objective of the earliest seed "analysts" (who functioned at least 800 years before the Christian era!), but there is equally no doubt that to-day most seed testing is performed in the service of commerce. As a matter of economy, or of economics, it is desirable that more tests should be made for the trade and fewer for the farmer and gardener. A ton of seed may be tested in one bulk as satisfactorily, and in some ways more satisfactorily, than the same ton split up into a hundred small parcels. Obviously it can be tested much more cheaply. It therefore seems common sense to encourage, or even to require, the testing and certification of large bulks in trade hands, when it becomes unnecessary to test the numerous small lots into which those bulks are divided. Theoretically, it further becomes unnecessary to test for retailers if wholesale bulks are certified. It would be so in practice if there were no fortuitous difficulties such as the holding over of unsold small stocks, dampness or overheating in stores, damage during transit and the like, and no temptation to fraud. It goes without saying, however, that a certain amount of retail testing and

testing for actual consumers will always be required in view of difficulties such as those referred to above, and for checking purposes. This argument takes no cognizance of the question of testing for farmers seed grown by themselves, which they propose to sow again on their own land or sell direct to other farmers. Tests of this kind, and tests for the information of a grower who has seed to offer to wholesalers, are clearly required.

Much mistaken effort has been expended in attempts to set up standardized methods of testing seeds to satisfy both the requirements of international trade and those of the husbandman. The essential in tests for trading purposes is to provide a basis for *comparison*, not a criterion of intrinsic value, and such a basis as shall offer the fewest chances of dispute when properly used. This implies *international standardization* of laboratory methods, and, as will be abundantly clear when analytical methods are examined later, the general acceptance of *numerous conventions*, both in the making and in the interpretation of tests. The actual user of seed, on the other hand, wishes to know exactly how many plants of the right kind an ounce or a pound of the sample in question will give him, and how many of the wrong kind (weeds), the nature of these latter, and what proportion is " inert " or will produce nothing. It is obvious that this precise information can never be given completely, because external conditions, varying from time to time and from field to field, exercise so much influence on the result of a sowing, but the analyst could *and should* inform the user on the points mentioned as they appear from his test *under optimum conditions*. At present he does not.

It is easily seen that the two main arguments here offered are not, on the face of them, compatible. If the user of the seed requires different information from that necessary to the trader, it does not apparently remain sufficient to test wholesale stocks and assume that results apply also to retail parcels drawn therefrom! This would be a sound objection if tests for the two purposes were made on the lines here suggested as more desirable, but it is not applicable as long as roughly standardized uniform methods of testing are employed for both purposes, as at present. Further, if a sufficiently extensive examination were made of relations between the two systems

when carried out *under optimum conditions*, details required by the grower could be accurately deduced from tests of the " trade " type; a different *interpretation* only of the figures obtained would be required.

A very big stride has been made during the past two decades towards unification of aims, standardization of methods, and the elimination of grounds for dispute, by the organization of an *International Seed-Testing Association.* This is a development from a European association that had been in existence a few years earlier, and its membership now includes almost all civilized States. Previous to 1939 triennial congresses of the association, in which representatives of seed-trade organizations also participate, sought by friendly discussion and agreement to elucidate knotty points in technique and interpretation, and gradually to elaborate an agreed system of testing and reporting acceptable to as many member States as possible. It is hoped before long to resume such meetings. Methods and rules approved by such congresses do not, however, have statutory value, and are, of course, over-ruled by the import regulations imposed by Governments of various countries. Nevertheless, an increasing number of countries now officially recognize the International Association's form of certificate as sufficient evidence of the quality of the consignment it accompanies and waive formalities in connexion with import of parcels so certified.

Seed Testing Technique.[1] THE PURITY TEST. An official—and reasonable—definition of pure seed is, " seed of the kind of which the parcel purports to consist." The simplest kind of purity test would therefore be, in a sample labelled *K*, separation into two portions—*K* and *not K*. Would that purity analyses were so straightforward! Even if they were there would be difficulties enough. To casual appearance it would seem easy to decide, once one were familiar, with the appearance of a given crop seed, whether the specimen were *K* or not *K*. The two most familiar grass seeds in European use are no doubt perennial ryegrass and Italian ryegrass. Typically they are so distinct in form that they could be distinguished in the

[1] Useful data and quantitative details are tabulated in Appendices I and II, pp. 138 et seq.

dark. Nevertheless, discrimination between these two provides one of the most toilsome jobs the seed analyst has to face. If Italian seed has lost its awn, as it very often has, a most trying and laborious scrutiny under a compound microscope must be undertaken to determine presence or absence of minute teeth on a particular section of a particular rib. Beyond simple separation of " pure seed " and " impurities," however, in established practice it is usual to segregate various types of impurity, according as they are harmful or only useless, and as they are living or non-living. The grades of impurity recognized as standard in the United Kingdom are (*a*) injurious weeds, (*b*) other weeds, (*c*) useful seeds of a species other than those of which the parcel purports to consist (" other useful species " on official certificates), and (*d*) inert matter.

Injurious Weeds. A few species were considered, at the time of drafting of the first English testing of seeds order (1917), to be specially objectionable. There were various reasons for their selection—some were listed because they were actually very harmful as weeds on the land (e.g. docks); some, apparently, because they were congeners of very harmful species (e.g. common sorrel); while with others the reason for their inclusion now seems rather obscure. Curiously enough, the parasitic dodder does not appear in this " injurious " list, although it is regarded with such distaste that under English law it has to be specially declared if present in clover in excess of very small specified numbers. While dodder is merely listed amongst " other weeds " its presence or absence must be specially shown on the purity report, so that the sender may see at a glance whether or not a sample of clover contains dodder. This stringent condemnation, combined with improved methods of cleaning and care on the part of farmers and merchants, has greatly reduced the incidence of this obnoxious parasite in English clover-producing districts. The British " injurious " list is as follows: Docks and sorrels (species of *Rumex*), cranebills (*Geranium*), wild carrot (*Daucus*), soft brome grasses (*Bromus*), and Yorkshire fog (*Holcus*). A list with many faults.

In other countries, naturally, other weeds are specially harmful, and a number of States issue lists of species of which the percentage permitted in imported seed is controlled.

Canada prohibits five species and lists many others as being noxious in various degrees; the United States of America cites about 100 species and regards samples containing more than 2 per cent by weight of such species as unfit to enter into the United States. In the Irish Weeds and Agricultural Seeds Act of 1909, as subsequently amended, and now current in Northern Ireland, docks, thistles, ragwort, and ox-eye daisy are specified as noxious, but this is for the purpose of compulsory destruction of the weeds on the land, not for seed trading purposes. Under the rules of the International Seed-Testing Association weeds are not at present grouped, but are all estimated together, in view of the difficulty of compiling a list suitable for all countries of specially objectionable species. Dodder, however, is separately mentioned.

In certain countries special provisions against individual species appear in the regulations governing trading or import. In England the law requires special declarations in connexion with suckling clovers (*Trifolium dubium* et spp.) in clover samples, and of burnet (*Poterium*) in parcels of sainfoin, in addition to that concerning dodder; for admission to Sweden, perennial ryegrass must be certified to contain less than a prescribed percentage (8 per cent at present) of ryegrass seeds which react to a particular test (the Hellbo test, see p. 87) for Italian characteristics; and for importation to France the content of *Bromus* or of *Vulpia* must be less than (at present) 5 per cent.

Other Weeds. It is not always simple to decide whether a given species is a weed or not. About the huge majority of species met with in commerce there is no doubt, but dubious instances often crop up. For example, burnet, specially mentioned in the English regulations as objectionable in sainfoin, is sown as a pasture crop plant in England itself; one species of melilot (*Melilotus alba*), an objectionable impurity, is largely sown under the name of sweet clover in America; *Poa pratensis*, our smooth-stalked meadow grass, here regarded as an impurity in samples of the rough-stalked species (*P. trivialis*), is one of the two most important pasture grasses in the United States, where it is famous as Kentucky bluegrass. The decision in such instances as these must be

decided by the agricultural value of the plant in the country concerned.

Some countries include, under the head of " other weeds " the fruiting bodies of parasitic fungi when they occur. Others place them under " inert matter." Strictly speaking they are neither. It is more convenient, however, to include them under one of these groups, since it avoids the necessity of introducing a special category to deal with them. From the practical point of view it is immaterial under which heading they are shown, provided attention is drawn to their presence. The most commonly occurring are the *sclerotia* of various strains of ergot (*Claviceps* spp.) in grain and grass seed samples. Those of *Sclerotinia trifoliorum* may occasionally be met with in samples of clover. These and other common diseases are discussed in a later section (pp. 63 et seq.).

The nature of the weeds in a sample is often a very useful guide to the origin of the sample. A prominent instance is their use in discriminating between wild white clovers harvested from an old pasture and " once grown " on arable land respectively. Naturally, the produce of an arable crop will contain annual arable land weeds such as soft cranesbill and chickweed, while that from an old pasture should not contain arable weeds, but may be expected to carry perennial pasture species such as crested dogstail or *Agrostis*. Again, certain weeds are useful as indicating the country in which a crop was grown. The small Umbellifer *Ammi majus* and the composite *Ambrosia artemisiaefolia* indicate Chilean and North American origin respectively when found in red clover. The grasses *Phalaris nodosa* in white clover suggests New Zealand. In this connexion it is to be observed that in view of the international traffic in seeds, which has been going on for generations, weeds have been transported to new areas all over the globe, so that in very few instances are they to-day really diagnostic, though they may often be strongly indicative.

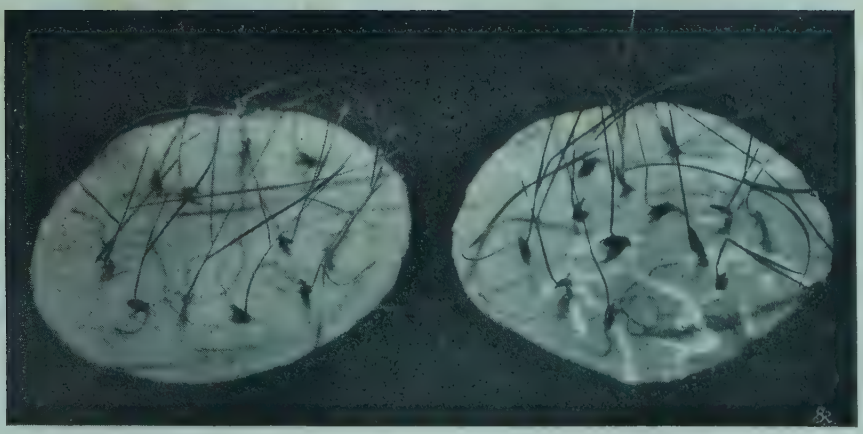
A point of weakness in current methods of seed testing emerges in connexion with weed seeds. In usual practice they are not tested for germination, and the recipient of an analysis is very apt to assume that all the weed seed mentioned will grow. This is of course often untrue—in fact, taking

D TECHNOLOGICAL RESEARCH
LIBRARY

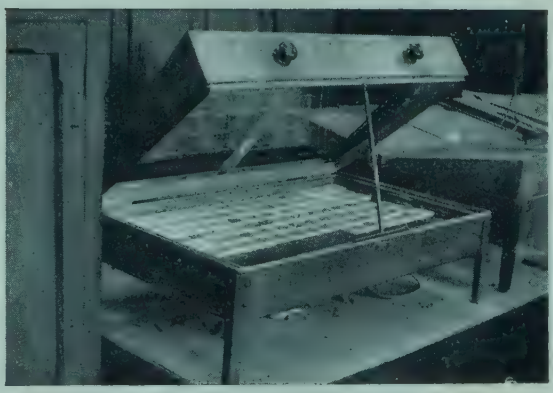
weeds as a whole, their germinability is generally *slightly less* than that of the " pure seed " of the sample in which they occur, and this itself is almost always below 100 per cent.

In a standard analysis report, weed seeds as well as other impurity fractions and pure seed are stated as percentages *by weight.* This practice, although established by long usage, might well be improved. A moment's consideration shows that 1 per cent by weight of a large seed means something totally different from 1 per cent by weight of a small one. If a sample contains 1 per cent by weight of soft brome, this will mean about 1,200 seeds of soft brome in every pound, but if the same percentage of chickweed is present, every pound of the sample will contain some 45,000 chickweed seeds. It is an occasional and a good practice to report the *number* of weeds per pound of the sample in addition to the percentage figure by weight. Properly to assess the effect of the weed content it is necessary to know both proportion by weight and by number; the former tells the purchaser what proportion of his money is being expended on weeds and the latter how many weeds he will be sowing per acre. The same remarks apply to the " other useful species " fraction, though here the omission to report numbers is obviously of less importance except with fine turf-producing grasses. The inert fraction cannot of course be reported by number, by reason of its nature, and it would be fruitless information even if it were possible to give it, since inert matter will not grow.

Useful Impurities. This fraction relatively seldom presents difficulty. There is no great problem in diagnosing barley among wheat or cocksfoot among ryegrass. A number of instances crop up, however, in which special methods must be applied to discriminate between closely similar species. Prominent instances of such resemblance are: meadow fescue and perennial ryegrass; rough-stalked *Poa* and smooth-stalked *Poa*; unripe or old alsike clover and unripe or old white clover; turnip and rape; six-rowed barley and two-rowed barley; mixed species of *Agrostis* (bent). The special characters employed in the diagnosis of these and similar difficult circumstances are noted in the later descriptive section of this book. In some instances, when a microscope must be used, the analysis of



A B



C D

E F

FIG. 7.—A, B—Gentner test; *Left*, perennial ryegrass germinating on filter paper showing no fluorescence; *Right*, Italian ryegrass showing fluorescence. C—Cereals germinated in sand dishes. D—Rodewald germinator. E—Jacobsen germinator. F—Hearson cabinet incubator.

FIG. 8.—A modern laboratory for purity tests.

FIG. 9.—A purity test in progress.

any material amount of the mixture is a very laborious task, and it is conventionally agreed that proportions may then be determined by separation of a much smaller amount than that of the standard analytical sample.

Inert Matter. This fraction probably gives rise to more disputes than any other. With grass seeds the question of inert matter has given rise to world-wide controversy as to whether or not the *empty husks* of the species of which the parcel purports to consist be considered *inert matter* or pure seed? On the face of it, it might appear that there could be no such question—that empty husks are in fact inert and that should settle it. Further, a husk that does contain a kernel, if that kernel is too immature or too much damaged to grow, is in fact inert, and so, on principle, should go into the inert fraction. If this be accepted the analyst is left to decide for himself in every instance of an undeveloped kernel, whether the latter is sufficiently mature to grow, and this immediately introduces a very bad " personal " factor. All degrees of development, ranging from fully mature, through various immature stages down to empty, may often be found together in the same sample, and two analysts may differ very materially in their placing of the dividing line between " sufficiently mature " and " insufficiently mature." It may be answered that capability to germinate can be decided by the germination test which follows the purity analysis. If so, what is the objection to leaving in the pure seed husks which are completely empty (if of the right species), for these will also be shown up by the germination test, while much labour and frequent disputes will be avoided. Thus the question is not so stupid as at first appeared. It is of importance because, while purity is estimated by weight, germination is estimated by number. The retention or rejection of a few empty husks therefore, in weighing the pure seed fraction, makes relatively little difference since the husk weighs much less than the full seed (about one-fifth as much in, say, ryegrass or cocksfoot), but in the germination test the same few husks will make a proportionately much greater difference to the percentage, one in each hundred being 1 per cent whether light or heavy. In the specific instance of perennial ryegrass, one empty husk per hundred " seed "

will affect the purity test to the extent of 0·2 per cent, and the germination test to the tune of 1·0 per cent.

In practice both systems are in operation; that which treats empty husks, if of the right species, as " pure seed " is known as the " Irish method," and the alternative, under which empty husk of all kinds is relegated to " inert matter," as the " Continental method." The International Seed-Testing Association recognizes the latter as standard.

In legumes and other huskless seeds the chief difficulty arises among cracked and broken grains. To crack a seed or even to break a piece off it does not kill it. Placed on the germinator or in the soil such a seed will make an attempt to produce a seedling. The criterion of germinability is agreed to be the capacity to produce a healthy seedling, and a further convention defines the minimum requirements for the constitution of a healthy seedling. In the purity analysis, seeds that are broken or injured to an extent rendering them incapable of producing a healthy seedling when sown under optimum conditions are rejected as inert. The analyst then is left to judge whether any individual injury is sufficiently grave to occasion such failure. It will be seen from Fig. 2 that in clover seeds the most exposed and thus most vulnerable part of the seed is the radicle. In germination the first visible growth is extrusion of the radicle, and the conventional (and, in general, sound) view is that if the radicle develops the plumule can be counted upon to follow, so that in a germination test the production of the root only is taken as guaranteeing capacity to produce a seedling. By reason, no doubt, of this position of importance assumed by (or imposed upon) the radicle, and because the active growing centre of that organ is very near the tip, it was for long believed that injury to the radicle tip was a very grave form of damage, and seeds in which the " noses " were broken were automatically rejected as " broken seed," i.e. broken to an extent rendering them incapable of seedling production. This is not strictly true, however; experiments have shown that both on the germinator and in the soil, seedlings having the radicle tips broken off, even with a considerable length of radicle behind the tip also missing, can produce adequate branch roots and a healthy plant.

It is clear, too, that in seeds of the legume or turnip type, where the main bulk of the seed consists of thickened cotyledons, the useful post-germination life of which is very brief in any event, and which in many instances (e.g. pea) do not even come above ground, very considerable damage may be sustained by these seed-leaves without material harm to the seedling. It becomes plain, then, that the most sensitive area of such seeds is that of, and immediately surrounding, the point of union (or rather, perhaps, common origin) of radicle, plumule, and cotyledons—that is, a small area at the " north " end of the seed. Even small cracks in this position must be viewed with suspicion, for a small crack in the testa may indicate actual breakage of the tissues within, and of course if a piece at the northern extremity is actually broken away the seed is obviously useless. Seeds broken internally and finding their way on to the germinator may cause serious trouble and dispute because they often extrude their radicle tips in an apparently quite normal way—being in fact alive although internally dismembered—and if the first count from the germinator is made at an early stage, they may easily be counted off as good seedlings, while if they remained another day or two they would expand sufficiently to exhibit their injuries and would then be rejected as officially non-germinable. In graminaceous and other albuminous species the area occupied by the embryo is naturally the most delicate part, but the shape of most seeds of this type, and the manner in which the embryo is inserted, combine to protect the latter, so that in practice embryo damage is uncommon, unless caused by vermin such as mice or insects. The most exposed part of the embryo in the gramineæ is again the radicle (Fig. 2), but here even more readily than among legumes a damaged main root produces secondary lateral roots, and it will be remembered that under normal conditions of soil-moisture the permanent root system in grasses and cereals is adventitious, the primary roots being temporary only.

Immature kernels in grass seeds, particularly cocksfoot, sometimes give a good deal of trouble. It has not been found possible to set up a standard criterion by which maturity can be measured by inspection. As a guide, it may be borne in mind that the development of endosperm (which can be seen

by transmitted light or felt by stroking with a thin flexible instrument or the finger-nail) does usually guarantee that fertilization has taken place, and this is of course the first necessity for viability. Fertilization alone, however, does not imply capacity to germinate; embryogenetic development is usually accompanied *more or less* in parallel by endosperm accumulation, and so in practice the size and form of the endosperm mass is used as a gauge of maturity. It appears in transmitted light as a translucent yellowish horny-looking streak, making its appearance first at the base of the kernel in the region of the embryo, later extending upwards towards the tip of the grain before expanding to any great extent in breadth. Eventually of course it appears to occupy the whole grain and does in fact nearly do so. *Very roughly speaking* a kernel will generally grow if the endosperm streak is half the length of the grain or more *and* has a width of approximately one-seventh its length, but it must be emphasized that this is only an approximate guide and cannot be applied by rule of thumb. Comparisons with length and breadth of rachilla (p. 87), which are tempting, are of no value; they do not show any constant relation.

Special provision is made in British seeds regulations for immature seeds in carrot. It is quite common to find 8 or 10 per cent of under-developed individuals in this species, most of them much smaller than the normal mature seed, but resisting removal during machining on account of the rough spinous nature of the seed.

Seed damaged by vermin is commonly useless. The following notes will be generally useful:

> The embryo of a cereal grain attracts mice, which eat it out with the most admirable precision and leave a neat conical pile without materially marauding the endosperm. Insect larvæ more often tunnel in the flesh of the cotyledons in ex-albuminous seeds, and while a little damage here is not dangerous, the tunnels very often reach into the northern danger-zone; indeed, a seed that only shows to outward appearance a minute round hole in the side or even only a small circular light-coloured area in the skin (weevilled pea) may be found almost wholly hollow within. Mites are very common in old seed of cruciferous crops, but are not usually parasitic. Badly stored seeds of many kinds

are attacked by weevils (*Bruchus* et al.). Wheat and some grasses are subject to eelworm attack (*Tylenchus* spp.), and kernels so affected have a twisted and shrunken appearance, usually associated with an irregular brown discoloration. In wheat these two characteristics are indicated in the popular names " ear cockles " and " burnt corn."

Grass seeds are reasonably free from insect parasites,with the exception of meadow foxtail (*Alopecurus pratensis*), which suffers dreadfully from the attentions of several species of gall midge (*Oligotrophus*, *Contarinia*). These lay eggs in the flower at the time of pollination and the larvæ feed on and completely destroy the developing kernel. The threshed seed is then either quite empty or occupied by the midge pupa instead of a grain. The insects are often themselves parasitized by an *Ichneumon*, but too late to save the seed. Samples may contain up to 90 per cent of worthless seed. Fortunately, from this point of view, foxtail seed is used very little in the United Kingdom; its price *per germinable seed* is, naturally, very high.

TECHNIQUE OF THE PURITY TEST. 1. *Sampling*. The analysis of a sample of small seeds is a slow process, every particle in it having to be examined. Hence samples must be small, though a single sample may have to represent a shipment of some tons of seed. Obviously, therefore, sampling is a factor of the very highest importance in the complete assay, for clearly if a sample is not representative it is worse than useless. A parcel of seed is not a homogeneous mass, and it is not practicable to mix it so thoroughly that any portion taken at random will be of a constitution exactly similar to that of the mass as a whole. For this reason a number of proportions must be taken from various parts of the bulk and be mixed. It is then possible to remix this small amount to a somewhat more uniform condition and it may then be reduced further by again drawing similar sub-samples from various parts of it. Essentially, this applies as well to the analytical sample used in the laboratory as to the bulk sample drawn in the warehouse, and in practice some variant of the same sampling method is used for both, though the detail of technique may differ.

In *Warehouse Sampling* it would obviously be most convenient for commerce if a single sample might be used to represent any given bulk, but it is generally regarded as more difficult to draw a truly representative single sample from a large bulk

than from a small one. Hence under International rules the greatest amount for which one sample is regarded as sufficient is 100 bags. Frequently, however, larger amounts are shipped upon the authority of a single sample, when the deal is not officially controlled, and it must be said that modern mixing machinery is remarkably efficient and serious discrepancies in wholesale shipments are much less frequent than might be supposed.

When seed is passing through cleaning machinery it is sampled by taking small portions at regular intervals from the final delivery stream. When it is a bulk heap, portions are taken from numerous points distributed over all parts of the heap. When it is in bags, portions are taken from each bag if there are few, or from one bag in so many if they are numerous. Portions should be taken from the top, middle, and bottom of each bag sampled, since small seeds among larger ones may shake down and gather in the lower part of the bag. In any given instance the samples so drawn are remixed thoroughly and a smaller sample taken from the mixture. The final size of sample submitted to the analyst varies from ¼ oz. of the smallest seeds, or 2 oz. for seeds of average size like cocksfoot or timothy, up to 8 oz. for very large seeds such as beans. Instruments for drawing samples from bags are available; the most generally satisfactory is the "walking-stick" type, which samples the bag at all depths simultaneously.

With regard to *Laboratory Sampling*, even the weights mentioned above are too great for an analyst to examine minutely as a routine practice, so that when he receives the warehouse sample it is his first business to draw from it a smaller analytical sample. Various methods are employed for this process, but always the first essential is to mix the bulk sample thoroughly. This may be done by turning the seed over and over by means of a spatula or by repeatedly pouring it in thin layers from a scoop, over such an area of the table that each scoopful will provide several superimposed layers. The division may then be performed by some mechanical contrivance, of which there are several available; or by taking small portions from various parts of the seed spread in a thin layer on a tray, using a flat

sharp-edged spoon for the purpose; or by "repeated division." The last named, while laborious, is generally found the most satisfactory method and is widely used. The mixed bulk sample is poured in a heap on a smooth table and by means of a flat straight-edged spatula divided into approximately equal halves. Each half is re-halved, each quarter again halved and so on until, say, thirty-two small, nearly equal heaps are obtained. Every alternate heap is discarded, the remainder remixed and the process repeated until a final sample of about the size required is obtained. The whole of this may then be weighed and analysed or it may be adjusted by adding or extracting small pinches of seed until an exact predetermined weight is obtained. This process can be "mechanized" by the use of a sampling grid constructed of light material that is used by spreading the seed in an even layer on a tray into which the grid exactly fits, laying the grid open side downwards on it, placing a similar tray on top, inverting the whole and picking up the grid, which automatically removes one-half of the sample in fifty small uniformly distributed portions, every alternate square of the grid being provided with a bottom. This has the advantages of quickness, even distribution of the removed portions, and ease of making a large number of sub-divisions. Samples are always drawn in duplicate and the results of two duplicates after analysis are averaged.

2. *Analysis.* The weighed analytical sample is transferred to a smooth table or glass plate and examined particle by particle, a few grains at a time being drawn from the heap by means of a knife or spatula and separated into "pure" and "impurity" piles. The impurity is then re-examined and divided into its grades. With practice most purity analyses can be made with only occasional use of a lens. The use of a lens is undesirable if it can reasonably be avoided, tempting though lenses are. Magnification is necessary, however, for such purposes as scrutiny of small cracks and the identification of tiny weed seeds.

Examination of grass seeds for presence and condition of kernel may be made either by feel or by sight. In feeling, one seed at a time is held by forceps or finger and stroked very lightly from base to tip with a thin flexible blade of steel, horn, or

bone, or with long finger-nail. Proficiency requires much practice, especially in handling species with hard husks, and great care must always be exercised to avoid damage to the kernel by squeezing, cutting, or abrasion. A better method is by means of a *diaphanoscope*, a satisfactory form of which is shown in Fig. 6. A beam of light is passed through a glass plate across which the seeds are passed under scrutiny from a low angle. The kernels can actually be seen by this method, and of course in doubtful instances stroking may be employed to assist sight. This process is easy in such instances as ryegrass when the seed lies on its back, but in types like cocksfoot, keeled and lying on their sides, it may be difficult enough. Trouble may often be saved by *blowing* the sample before examining it for kernel. There are several ways of doing this. The *drøfter truge* has already been mentioned. A method requiring less knack but more apparatus is the Dutch system employing a controlled vertical blast of air in a metal tube closed top and bottom by a piece of stretched muslin (organdie) through which the air can pass but the seeds cannot, and partially closed at two intervals by sloping metal baffle plates reaching somewhat more than half across the tube (Fig. 6). These plates retain any seeds falling upon them. The seed being placed on the lowest muslin and the air blast being adjusted to suit the nature of the sample, the latter is sorted into three grades, the full heavy seed remaining on the lower muslin, the light empty seed being blown to the top and falling back on the upper metal baffle, and the middle baffle, collecting seed of moderate weight which will consist chiefly of seeds with kernels but may contain a few empty husks. The checking over of these grades on the diaphanoscope is then a relatively rapid job.

Dodder in clover or timothy may be sought by a spatula and lens examination on the table, but as the whole warehouse sample has usually to be examined for this parasite such a method is terribly slow and laborious. It is better done on a " dodder machine " which feeds the seed slowly on to a travelling endless band of black velvet, in a layer one seed thick, and passes it under a fixed reading lens for review. This method takes about a third of the time used in a " hand " examination (Fig. 5).

The various impurities or grades of impurities being separated, their constitution, identity of weed seeds, nature of inert matter, etc., are noted, and they are weighed on an ordinary chemical balance or on one of the balances specially designed for quick weighing of small quantities (Fig. 8). As a check, the pure seed is also weighed. Percentage proportions are then calculated.

It will be realized that great care and accuracy are required both in analysis and weighing, when it is remembered that in calculating percentage any error is multiplied by 50 in the common instances in which a two-gramme analytical sample is used, by 100 if only one gramme is taken, and by 400 in such a case as *Agrostis*, of which a quarter of a gramme is analysed. Trouble may occasionally be experienced, even through the slight gain or loss of water vapour in a grass seed sample, during the process of analysis.

3. *Weight.* It has been shown in an earlier section that the weight of a seed may easily be given too much importance. Nevertheless, it is often desirable to know for purposes of comparison (*a*) the actual weight of an average grain in a sample, or (*b*) the weight of a unit volume of the sample in the mass. The former is usually expressed as the weight of a hundred grains for large seeds or of a thousand (= " thousand weight " or " M weight ") for small seeds, because the tiny fraction required to express the weight of one individual " pickle " would be inconvenient. Ten, or sometimes five, lots of 100 (or a multiple of 100) seeds are counted at random from the pure seed, the lots weighed and the weights averaged. Importance is attached to these " absolute " weights in certain crops, of which flax is an example.

Bushel weight, or the weight in pounds of an imperial bushel, is chiefly quoted in connexion with cereals and grasses. In the warehouse this figure is obtained by filling an actual bushel measure and weighing it. This is done several times and the weights averaged. The seed analyst in the laboratory, however, having only a small hand sample upon which to work, obviously cannot do this. He uses a *chondrometer*. This is a balance resembling the " Westphal " instrument, having a graduated beam balanced on a knife edge, carrying a sliding

" rider " weight at one end, and furnished at the other with a hook from which is hung a metal bucket filled with the seed under test. The bucket is an aliquot part of an imperial bushel (commonly half a pint). The graduation of the beam is arranged in relation to the bucket capacity so that when the latter is filled level and the rider adjusted to balance the beam, the weight per bushel may be read off directly (Fig. 5).

The chondrometer is liable to considerable errors if not carefully used. It is easy to leave less or more seed in the bucket, when the top is struck off level, by heavy and quick, or light and slow, use of the *cursor* (the straight-edge with which the levelling off is done). Variations may easily occur even when the bushel itself is used, but with the chondrometer any error in filling is naturally multiplied in the reading.

4. *Moisture.* It will be understood from the discussion in the preceding section of this book that moisture content is an important consideration, especially if the seed is to be stored or transported. The common method of estimating moisture is that in general use in chemical laboratories, namely, by drying a weighed quantity of the sample in a steam oven at a temperature of about 98° C., cooling in a closed desiccator and re-weighing. Seeds that are alive at the outset do not dry easily, and by this method the sample may have to remain two days in the oven. An objection to protracted heating is the danger of re-gain in weight by oxidation of the oils which most seeds contain in some degree. Grinding the seed before heating does not seem to hasten matters much and probably somewhat augments the danger of oxidation. Drying can be achieved more expeditiously and satisfactorily by the use of an electrically heated and thermostatically controlled oven by the method laid down under the rules of the International Seed-Testing Association, which stipulate that the test sample should be placed in a cool oven and heated, and then kept at 103° C. for five hours. Weighing is best performed in an air-tight vessel, since dried seed, especially of grasses, re-absorbs moisture from the air with great ease and speed, and the weight of the sample, if open, may gain materially while actually on the balance. Portions of about 2 grammes in weight (about one-fourteenth ounce) are generally used, and

the estimation is made in duplicate. It is important that *samples intended for moisture estimations should be transmitted in air-tight containers.*

5. *Diseases.* The analyst should be able to recognize by inspection the diseases that commonly occur among commercial seeds which exhibit external " symptoms." Common insect pests have been noted on p. 57. The more frequent fungoid diseases are mentioned below, under their appropriate hosts:

CEREALS. *Bunt*, caused by the fungus *Tilletia caries*, affects *wheat*. The grain becomes entirely filled by a sooty mass of " *brandspores*," reproductive bodies of the fungus. The testa remains intact unless mechanically broken and the grain is shorter and rounder in shape than the normal wheat grain. Bunt spores are globular, nearly black in colour and easily recognized among spores of their type by their large size (diameter $\frac{1}{50}$ mm.) and by the strong network of ridges with which they are covered (Fig. 10).

Smuts may affect *wheat*, *barley*, or *oats* (and rarely rye). The causal fungi of most of them are species of *Ustilago*, relatives of the bunt fungus. In some instances the spores are liberated from the destroyed floret in which they are formed and dispersed among healthy seeds. They may then be found distributed generally over the grains, accumulating in the groove and among the apical hairs of wheat, and in the folds and furrows of the glumes of oats or barley. If they are plentiful they may be detected by the eye, unaided or with a lens. If few they are best collected by moistening the seed with alcohol in a watch-glass and adding water. The mixing of alcohol and water sets up convection currents, which dislodge the spores. The washings may then be examined microscopically. Smut spores are similar in structure to those of bunt, but smaller and either smooth or *slightly* roughened, not netted. Their size and degree of roughness help mycologists to differentiate the species.

Certain of the smut diseases (e.g. loose smut of wheat) are not externally visible either as spores or by other characters on the grain, but the fungus may be present inside the cells of the kernel. These obviously cannot be detected during ordinary analysis.

In the disease known as ergot, the fungus (a species of *Claviceps*) replaces the kernel by a solid mass of its own vegetative tissue, made up of tightly interwoven threads. On the outside this mass, or *sclerotium*, is chocolate or purplish or grey-black in colour, and inside, if broken across, is found to be faintly violet or nearly white. The sclerotium is usually sausage- or horn-shaped and is larger than the grain it replaces. Ergot may often be met with in samples of rye, especially of northern

European origin, less commonly among other cereals. In grain intended for human or stock food it is an important impurity in view of its capacity, if eaten, to induce abortion in females. Fortunately it is seldom present in home-produced cereals in more than a trace by weight and as a field disease it also does little harm in this country. Forms of ergot with smaller sclerotia are common on wild grasses (see below).

Grasses. *Ergot* is the only disease the analyst usually meets in grass seed samples. Wild grasses are very commonly affected, particularly Yorkshire fog. The sclerotia of Yorkshire fog ergot may be found in many clover and grass species, the host having been growing as a weed in the seed crop. Sclerotia belonging to the cultivated crop itself may be found in ryegrass, cocksfoot, and more rarely other species. They are much smaller than, but similar in appearance to, the sclerotia of cereal ergot and it is possible to mistake them for mouse excreta. Their appearance when broken across distinguishes them. The disease is not serious in United Kingdom crops.

Clovers. *Ergot* may be found, as noted above, it having developed on grasses among the clover seed crop. It does not attack clovers themselves.

Clover sickness in its commonest form is caused by the fungus *Sclerotinia trifoliorum*, and the sclerotia of this may occur in red clover samples. It is rare in other clover if of British origin. Such sclerotia are black or nearly so in colour and irregular in outline with a flattish cross-section.

Celery. The so-called Rust or leaf-spot disease of celery is carried by the seed. Close examination is required to detect it, a high-power lens or binocular microscope being used. The fruit bodies of the fungus responsible (*Septoria apii*) appear as minute black dots on the surface of the seed.

A number of seed-borne diseases are detectable during the germination test, though not visible during purity analysis. In such instances the identification usually depends upon the production of fungus spores, induced by the warm moist conditions of the germinator. The following are of reasonably frequent occurrence.

Mangolds and Beet. *Phoma* disease or "*blackleg*" causes the young seedlings during the germination test to sicken and become discoloured with a tendency to collapse. Spores of the fungus, aggregated in tiny, sticky, finger-like tendrils, are exuded from fruit bodies in the diseased tissues and may be observed by microscopic examination.

Peas. Spot disease, caused by the fungus *Ascochyta pisi*, gives rise to more or less rounded light-coloured spots, which may become sprinkled with minute dark specks (fruiting bodies), which later bear characteristic colourless spores identifiable under the microscope.

Oats and Barley. Leaf-stripe disease, carried on the seed, may be betrayed by mould developing in the germinator, rarely bearing large multi-celled spores typical of the two species of *Helminthosporium* concerned.

Flax. The cotyledons of flax sometimes develop brown diseased spots caused by invasion of the fungus *Colletotrichum lini*, responsible for the disease called " seedling blight."

Poisonous Fungi. The poisonous nature of ergot has been noted. Poisonous internal fungi are carried by darnel grass (*Lolium temulentum*), which very rarely occurs in samples from this country, but may be met with in imported cereals. An important instance that deserves special mention is that of the poisonous fungus *Gibberella Saubinetii* which attacks barley, causing " footrot " and ear blight. Cases of poisoning in pigs fed upon barley meal made from infected grain have been recorded, and if barley likely to be used for feeding goes mouldy in the germinator and is suspected it should be submitted to a pathologist for examination.

In germinating seeds in husk, such as grasses, it should be borne in mind that the husk is dead. Saprophytic fungi may very well develop upon such dead envelopes, and mould appear. *Penicillium*, *Aspergillus*, *Mucor*, and many others may occur in this way. Care should be exercised not to confuse such mouldiness with parasitic infection—a fungus is not parasitic until it attacks and injures the *living* kernel. It will be noticed in practice that " seeds " that do contain a living kernel have not usually much tendency to go mouldy in a clean germinator, in spite of their dead husks. Among huskless seeds, onion is particularly subject to profuse development of mould.

6. *Provenance.* It is often of importance to know the country of origin of a stock of seed, for strains of the same species grown in different areas frequently differ in their agricultural characteristics, and may be specially suitable, or unsuitable, for the purpose of the purchaser. The objective evidence upon which the analyst must base his opinion obviously falls under two heads, namely, the qualities of the seed itself and the kind of impurities it contains. In general, the latter is the more useful as offering more scope for variation and characterization. Numerous workers have investigated this field during the past three decades and the analyses arrived at tend to

become more and more mathematical and less and less biological. This is natural, in view of the constant and increasing international traffic in seeds, which must have a unifying effect upon such critiera as weed floras.

No attempt is made here to give detailed instructions for determining provenance, but simply an account of the methods employed and of the data to be sought. In the first place it must be emphasized that only in the rarest instances are single diagnostic characters to be found. An opinion must usually be formed upon an accumulation of data.

As regards *the seed itself*—size (and weight), colour, uniformity of ripening, and sometimes germinability are useful indicators. Among red clovers, for instance, produce from warm southern counties is " bolder "—i.e. larger, fuller—than that from more northerly latitudes. Italian and Chilean are among the large type. The same pair are in the bulk yellower than, say, English or North American seeds. The English climate is not well adapted to the production of plump, evenly ripened seed, and consequently English red clover commonly contains a higher proportion of brown and often of shrivelled grains than southern European or South American, and frequently a number of seeds still within their capsules.

Even among grasses colour of husk and kernel vary. New Zealand ryegrass may generally be spotted by the light colour and translucency of its glumes, and the relatively dark kernel showing through them.

Germination capacity is of course affected by so many factors that it is by itself an untrustworthy character for diagnosis, but taken with other indications it may be confirmatory. In most seasons, for instance, French Italian ryegrass will be expected to have a higher germination figure than British.

Among *impurities*, weeds are the most important. Mineral fragments and " useful " impurities may also serve their turn; one looks for timothy in Canadian samples of alsike but not in Swedish, and chalk particles would scarcely be expected in Scottish-grown wild white clover.

Individual weed seeds are seldom nowadays quite diagnostic, but it is still possible to form a shrewd opinion of origin from the *profusion* of some characteristic species. Familiar examples

are: the frequency of wild carrot (*Daucus carota*) in French red clover, of cut-leaved cranesbill (*Geranium dissectum*) in English, and of dodder in, say, Italian and Chilean.

Latterly, attention has been directed to the value of certain *combinations* of weed seeds and of the *proportion* in which they occur rather than to diagnostic value of the species in themselves. In this connexion it is of interest to mention that in an examination of 6,500 samples of English red clover at Cambridge, the seven most common weed seeds, in the order of frequency, were found to be: ribgrass, cut-leaved cranesbill, curled dock (*Rumex crispus*), white cockle (*Lychnis alba*), dove's foot or soft cranesbill (*Geranium molle*), field madder (*Sherardia arvensis*), self-heal (*Prunella vulgaris*).

Occasionally the occurrence of disease may be a useful guide to origin, but more usually as indicating countries in which a sample was *not* grown (where the disease in question does not occur) than one in which it *did* originate, for there are few diseases that appear in one country only.

There are possibilities in the " suction force " exhibited by different strains of a given species, that is, the speed with which they will absorb water from a solution (such as sugar syrup), but this has not yet been sufficiently explored.

THE GERMINATION TEST. Any attempt to define categorically the purpose of a germination test founders at once on the bicuspid rock whose crests are husbandman and merchant. It may suffice for our purpose to say that the accepted object of the laboratory test made upon an artificial substratum is to determine what percentage proportion by number of the " pure seeds " as isolated in the purity test are capable of producing healthy seedlings when sown under optimum conditions. This immediately raises the question, what is a healthy seedling? The generally accepted definition is that a healthy seedling must possess *a healthy root with root hairs, an intact plumular bud, and at least one healthy cotyledon.* It will be noted that in the huge group of plants called monocotyledons, embracing all the grasses and cereals, onions, leeks, and a number of ornamental species, one cotyledon is all the seedling can be expected to have, for one is the whole complement! In routine testing it is generally assumed that any seed extrud-

ing a healthy and hairy root would, if left on the germination bed, develop a satisfactory plumule. Whenever the former condition is fulfilled, therefore, the seed is usually "counted off" and thrown away *if* the analyst is satisfied that it has had time enough to manifest any breakages or mechanical injuries that may be present.

1. *Conditions.* We have noted that the factors within artificial control which induce or influence germination are: *moisture*, *warmth*, *oxygen*, and *light*. Any good system of testing must provide for manipulation of these, and upon the analyst's knowledge of requirements in these directions in the species he is handling depends the value of his results.

Moisture.—A steady and sparse supply is usually requisite. Germination seldom fails through too little water being given, unless the seed bed and seed are actually allowed to dry right out. It may, however, be retarded, and this in turn may lead to other difficulties. Broadly speaking, a seed should be kept supplied with about 50–60 per cent of its total water-holding capacity. Soaking before placing in the germinator is an advantage in certain instances, but in others it has been found a a disadvantage. For most ordinary agricultural seeds it is not required nor desirable, though it is sometimes of benefit to mangolds. Where pre-soaking is resorted to very little further water is supplied after "sowing" in the germinator. Certain species, of which cocksfoot is an example, seem particularly sensitive to over-doses of water in the germinator and resent swamping. The kind of water used generally depends upon the nature of supply available. Rain-water is said to be best, but its use is impracticable in most laboratories. Distilled water is definitely not desirable, being unaerated. There seems to be little difference in results as between soft and reasonably hard waters. Extremely hard water is probably best avoided. Cleanness and adequate freedom from bacterial or fungoid contamination are of course essential. A change to fresh water is desirable during the course of incubation upon any type of germinator that has a reservoir.

Temperature.—Within reasonable limits temperature affects speed of germination more than numbers germinating, but nevertheless most species have a fairly narrow optimum range and since it is the analyst's business to obtain from 100 seeds the greatest number of seedlings that he can obtain by fair means, he must provide each species, as far as he can, with its chosen temperature. The large bulk of farm and garden seeds will grow fairly satisfactorily at temperatures around 22° C.

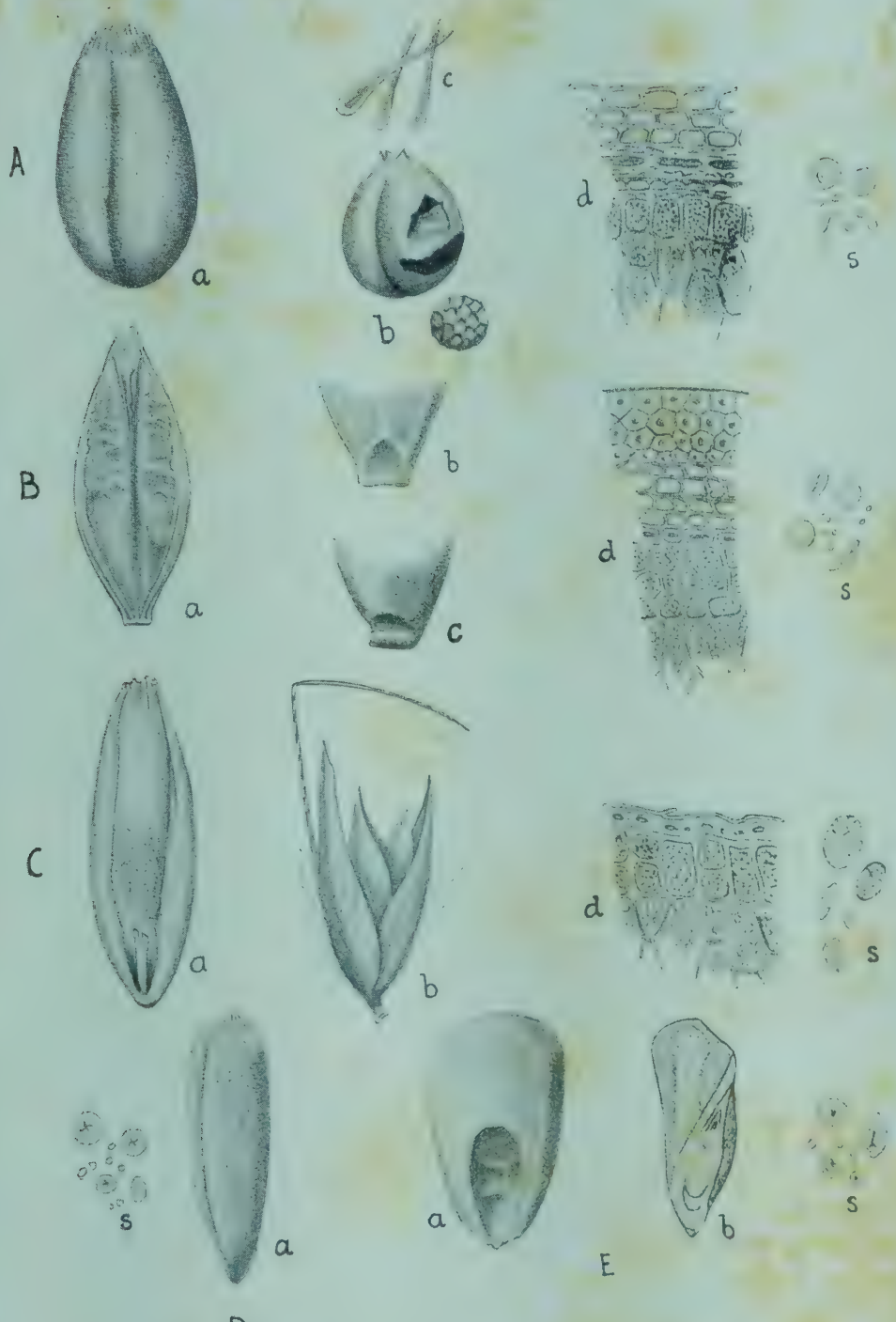


FIG. 10.—*Cereals*. A—Wheat. *a*, grain; *b*, bunt ball and brand spore; *c*, apical hairs; *d*, cross section through testa; *s*, starch.

B—Barley. *a*, grain; *b*, base of Chevalier type; *c*, base of Goldthorpe type; *d*, cross section through testa; *s*, starch.

C—Oat, *a*, common oat; *b*, *Avena sterilis*; *d*, cross section through testa; *s*, starch.

D—Rye. *a*, grain; *s*, starch.

E—Maize. *a*, grain; *b*, longitudinal section showing embryo, central floury, and outer horny endosperm; *s*, starch.

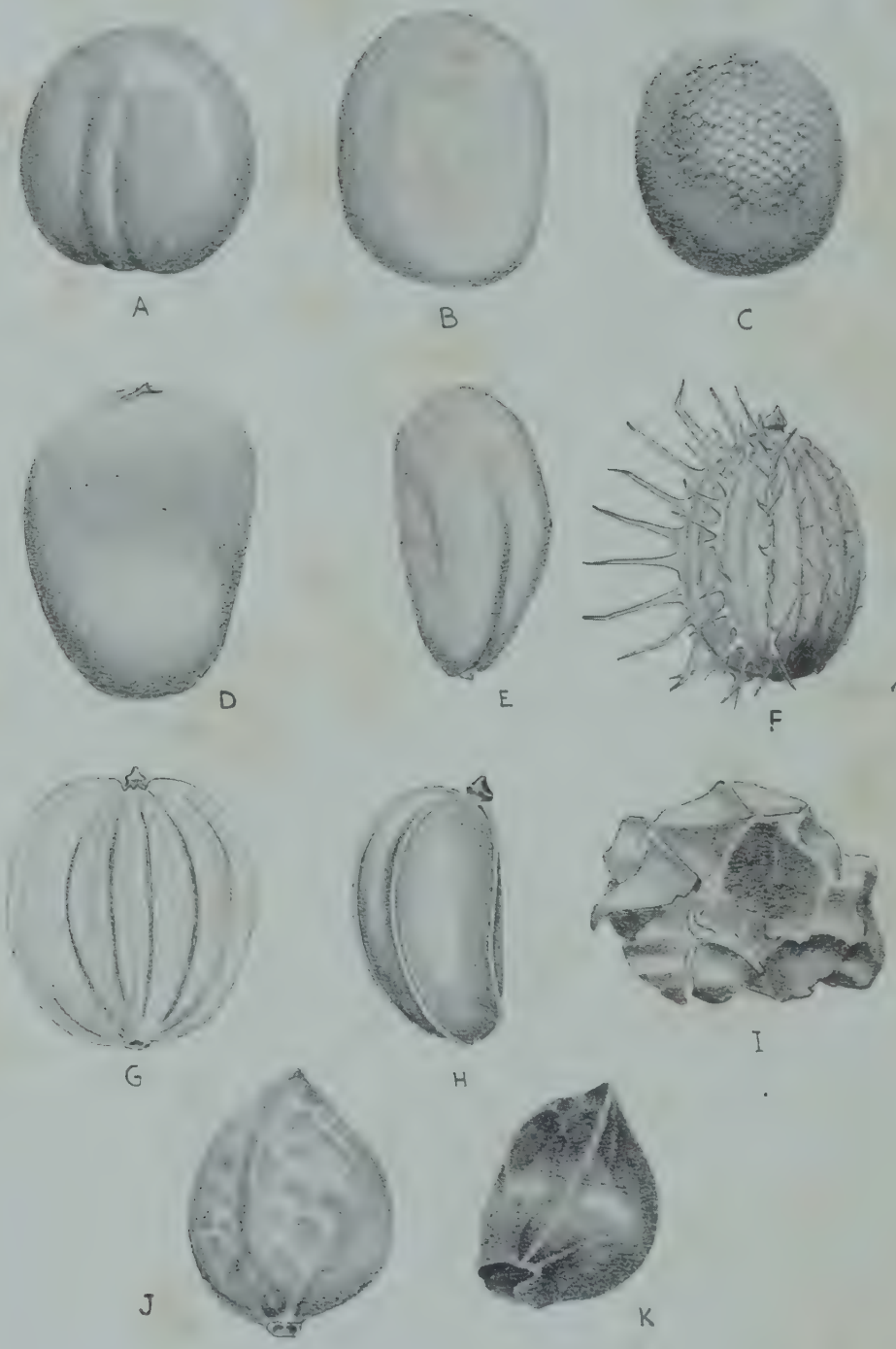


FIG. 11.—*Roots and Vegetables.* A—*Brassica* of turnip and cabbage type. B—White mustard. C—Black mustard. D—Radish. E—Cress. F—Carrot: *left*, natural; *right*, rubbed. G—Parsnip. H—Celery. I—Beet. J—Spinach. K—Onion, leek.

(= 71½° F.), and in a seed-testing station a number of incubators are always run at this temperature. Most species will stand higher temperatures under necessity, and a few are actually benefited by alteration between this and 30° C. (= 86° F.). Instances are to be found in mangolds, cocksfoot, and carrot. Frosted seed or seed affected by delayed germination (see pp. 9 and 10) should be tested at still lower temperatures. When feasible, seeds so affected will usually germinate satisfactorily after being " chilled " for two days at 5° C. (= 41° F.) and then brought back to room temperature.

Oxygen is plentiful in the atmosphere and is also supplied in solution in ordinary tap-water. Seed set to germinate must be ventilated, but it must be ventilated *without draughts*. This is important. The effect of a draught on a moist seed is to lower its temperature materially, and although this will not usually kill it, it will often prevent its germination within the period allowed for the test and it is then reckoned " dead." Supplying additional oxygen is no advantage—there is plenty in ordinary air and water.

Light.—Most seeds are germinated in diffused light as a matter of convenience, and most common sorts will grow as far as is required for the purpose of a test either in light or darkness. There are, however, instances in which light appears definitely beneficial, and others in which it prevents germination. *Poa* (meadow grasses) and *Agrostis* (bent), particularly if freshly harvested, are apparently helped by direct sunlight; ryegrasses germinate better in diffused light than in the dark, but less well in direct sunlight; *Nemophila* will only germinate in the dark; celery-leaved buttercup only in light.

There seems to be little practical difference in value for ordinary routine purposes between light of different *colours*, the seedlings not being allowed to develop far enough to require chlorophyll, but germinators are occasionally glazed with blue (cobalt) glass as a deterrent to moulds and bacteria.

Duration of Test.—Conventional periods are agreed on for full germination tests on the various species and these are noted in the table on pp. 142–144. In most instances these periods are somewhat longer than they really need be for practical purposes. The distinction between so-called *germination capacity* and *germination energy* is important. The *capacity* figure indicates the total number per cent of the seeds that have grown within the full conventional test period for the species; the *energy* figure the proportion that germinated *quickly*—that is, within a much shorter, stated period. The capacity figure is in universal use for the purpose of declaration and guarantee. For commercial use this is the better figure of the two, but as an indication, to the husbandman, of the sowing value of the sample, the energy figure is generally to be preferred, for a

sample that grows quickly grows vigorously and should give a better crop of seedlings in the field than a slower-growing sample of the same total germination capacity. Considerable care is necessary, however, in judging the potential germination strength from the rapidity of growth. Freshly-harvested seeds of many kinds often grow very slowly and irregularly under standard testing conditions, and even after the seed has been subjected to appropriate temperature adjustments, the initial counts may be low and quite misleading from an energy point of view. Seed that has been dressed with mercuric dust, particularly when the dust has been applied too heavily or to out-of-condition grain, may also be considerably slower in starting growth. Although the germination capacity has not been impaired the energy figure has lost any use as a guiding factor.

2. *Apparatus.* Germinators are referable to two main groups—those in which water supply is automatic and those in which water must be supplied to the seed beds by hand. The latter are evidently capable of greater response to personal skill and judgment, but the former, once calibrated, are subject to less personal errors and are much less laborious to operate. The most prominent forms in use at present are noted below, and shown in Fig. 7. The species for which they are principally employed are listed in the table on pp. 142–144.

Jacobsen.—A tank of water is kept at an even temperature by thermostatically controlled gas or electric heat. Glass strips placed across the tank carry filter-paper or blotting-paper pads, kept moist by a filter-paper strip or cotton wick dipping into the water below. Seeds are sown on the pads and covered by small ventilated bell-jars. Water supply is automatic and controlled by size of wick or wick-strip and by distance from water to pad.

Cabinets of various types. The usual principle is that of the egg incubator. The cabinet is jacketed with water, and gas or electric heat is controlled by a capsule or bimetallic thermostat. Seeds may be sown (*a*) on filter-papers placed in *petri dishes*, (*b*) between sheets of filter-paper laid upon or between folds of flannel, or (*c*) in dishes of sand or soil. Water supply must be given by hand from a wash-bottle jet or preferably from a spray. Whole rooms may be rigged as incubators on this principle.

Rodewald.—A tray of wet sand rests above a tray of water kept at an even temperature. Porous (unglazed) porcelain dishes or blocks are firmly bedded on (not in) the sand and seeds are sown thereon. Water is supplied to the sand by hand, and is

thence fed sparingly and regularly to the seed by the porous blocks.

Refrigerators are occasionally used. They may be jacketed with circulating cold water, or fitted with baskets for ice, or cooled by means of liquefied gases.

TECHNIQUE OF THE GERMINATION TEST. It is already understood that germination tests are made only upon " pure seed " from the purity analysis. The number of seeds used for the growth test varies with the species concerned, but the greatest number found practicable should be used in all instances. The usual practice in routine work is to " sow " either four or five separate hundreds. The lots of 100 each are counted at random from the pure seed and scattered on the chosen seed bed, adjusted if necessary to an even distribution, care being taken that no two are in contact. Thus all have equal access to the water supply and avoidance of contact reduces the possibility of mould, should it develop, spreading from an injured or dead seed to a healthy one. The cover appropriate to the method in use being placed over the seed bed, it should then not be necessary to touch the test again until the first germination " count " is made. This may be from two to five or six days according to the species under test. If water supply is not automatic, the initial supply given should last the requisite period up to " first count."

In counting out the hundreds, any tendency to selection of seed must be rigidly avoided. To this end it is desirable not to heap up the seed in a conical pile, for in such a pile the larger grains will tend to run down to the outside of the base of the cone and thus enjoy preference over the smaller grains in the mass. Where the sizes of particles are very variable within the same sample, it assists fairness to sieve the whole mass over standard sieves into two, three, or more grades, then count the total number in each grade and make up each hundred for the germinator with *proportional* numbers from each grade. This is usually done in testing mangolds, with which one may have " clusters " about a quarter-inch in diameter and others less than an eighth-inch in the same sample, with all grades in between.

As a check upon the conditions in the germinator it is desirable

to insert a test hundred of a " control " sample of the same species at the same time as the sample being tested, the true germination capacity of this control sample being known from repeated tests beforehand. Otherwise, in the event of a poor germination, the analyst cannot be quite certain whether the sample or the germinator is at fault.

At the expiry of the conventional period for " first count " the test is inspected and all healthy seedlings conforming to definition are picked off the seed bed, their number being noted, and discarded. Any individuals of which there is doubt as to their health or freedom from injury are left on the seed bed until a subsequent count in order to give time for any disabilities to become more conspicuous. The seeds remaining may with advantage be transferred to a fresh seed bed. Water is given if it is needed and the test returned to the germinator. Two or three times subsequently during the period of test this operation is repeated, the number of good seedlings being added to the record each time. At the end of the standard period for the test a final count is made, and total good seedlings, broken or diseased seedlings, hard seeds which have not imbibed water (with legumes), and remaining dead seeds are separately recorded. The average germination of the various lots then constitutes the germination performance (capacity) of the sample. Reasonable latitude must be allowed for " experimental error " (fortuitous variation) as between hundred and hundred, but if the variation is abnormally wide, the validity of the result becomes suspect and the whole test is repeated.

Artificial aids to germination.—It is agreed that only " fair means " may be employed to induce or facilitate germination. There is no *ex cathedra* pronouncement, however, as to what constitutes fair means. Fortunately it does not matter much, since to induce germination by any means, fair or otherwise, against nature is extremely difficult.

In grass seeds the husk delays entry of water and there are a few instances, of which tall oatgrass (*Arrhenatherum avenaceum*) is the commonest, where it is usual to " shell " out the kernel before placing on the germinator. If this has been done, the fact is stated on the analyst's report.

Chemicals are generally classed as unfair and when employed they are not often useful. It has been claimed for numerous compounds at various times that they assist germination.

Formates and nitrates (usually of soda or potash) have been prominent among such claimants. The advantage of their use is very dubious, except perhaps in testing freshly-harvested *Poa* and *Agrostis*, where the use of potassium nitrate may remove the necessity for direct sunshine.

Methods of combating " delayed germination " have been discussed (see p. 69). While various explanations have been offered, it may be that with oats the accumulation of respiratory carbon dioxide between the husk and the groat has some effect. Shelling out of the kernel often assists in instances of this kind, but should not be necessary with proper temperature controls.

Interpretation of Results. Anyone submitting a sample of seed for official testing in the United Kingdom is informed upon the following points:

(*a*) Percentage purity by weight.

(*b*) The percentage by weight of weed seeds present, with the names of the more important of them.

(*c*) The percentage by weight of " other useful " species present, with their names.

(*d*) The nature and percentage by weight of any inert matter present.

(*e*) Attention is drawn to any special features, such as presence (and amount if present) of dodder, presence of any diseases observable by inspection, and, in perennial ryegrass samples, proportion of awned seed.

(*f*) Germination energy—i.e. percentage by number of the " pure seeds " germinating in a short (stated) period.

(*g*) Germination capacity—i.e. percentage by number of the " pure seeds " germinating in the standard full period (not stated) for a germination test on the species concerned.

In addition, information *may* be given, or will be given if requested, upon:

(*h*) The bushel weight of the sample.

(*i*) The weight per 1,000 seeds.

(*j*) The percentage moisture content.

(*k*) The *number* of weed seeds per pound of the sample.

(*l*) The proportion of perennial ryegrass, if present, in a sample of Italian.

For the merchant the interpretation of such information is relatively simple. He buys and sells upon specific simple attributes: purity per cent; germination per cent; perhaps bushel weight; possibly freedom from impurity x; absence of excessive moisture, or excessive numbers of weed seed y, and so on. Only upon such lines could trade be conducted. If any attempt were made to chain commercial transactions to guarantees of productivity, the result would certainly be chaos.

For the husbandman the matter is not nearly so simple. He really does want to know what is going to happen when he sows the sample. He buys by weight and the first thing for him to do, therefore, is to determine what proportion by weight of the sample consists of seeds of the right kind *and* capable of growing. To find this he must multiply the germination percentage by the purity percentage and divide the product by 100. This figure used to be known as the *real value* of the sample. It is more generally quoted now as the *percentage of pure germinating seed.* If a sample has a purity of, say, 98·2 per cent and a germination of 87 per cent, the percentage of pure germinating seed will be $98{\cdot}2 \times 87 \div 100 = 85{\cdot}4$ per cent. When the sample is a legume containing hard seed it is justifiable for the private purpose of this calculation to add the total percentage of hard seed for lucerne (red clover one-half, other legumes one-third) to the germination figure before beginning the multiplication. In the example above, the husbandman now knows that if the seed is priced at, say, 1*s.* 6*d.* per lb., he is paying $18 \times 100 \div 85{\cdot}4 =$ 1*s.* 9*d.* per lb. for the useful seeds which he really wishes to buy. This at once affords him a useful means of comparing two or more samples. He cannot directly compare the sample above with another priced at 1*s.* 6½*d.* per lb. and showing a lower purity (say, 97·8 per cent) but a higher germination (say, 93 per cent); but if he proceeds to evaluate the second sample he finds that the 1*s.* 9*d.* in the first instance compares with 1*s.* 8*d.* in the second. Hence the higher-priced sample, neglecting all considerations except cost per lb. of pure germinating seed, is the cheaper. Next, since the percentage of pure germinating seeds is different for the two samples, the *number* of them in each lb. of the sample will be different. If, therefore, we suppose

that the husbandman intends sowing 4 lb. of the sample per acre, the number of seedlings to be expected from the two samples respectively will be in the proportion of $4 \times 85{\cdot}4 \div 100$ $(= 3{\cdot}42)$ to $4 \times 91 \div 100$ $(= 3{\cdot}64)$, or approximately the proportion of 10 to 11.

The next considerations is *speed of germination.* Quick and vigorous growth during the early life of the seedling means much to success, especially with root crops, which, during the seedling stage, are subject to attack by predatory insects. Moreover, slow germination may indicate old seed, or seed damaged by frost or for some other reason in bad condition, and this will imply an unnecessarily great reduction of the percentage of seedlings when sown in the soil. As previously pointed out, however (p. 70) slow germination does not necessarily imply weakness of vitality. Still, as a general rule high laboratory germination suffers less proportionate reduction in the field than a low one. This is most marked in flax. The author's experience with red and white clovers and with rye-grasses has been that while a laboratory germination of, say, about 95 per cent has given a growth in soil of about 90, a laboratory figure of, say, 70 has been represented by perhaps 40 in the field, and laboratory results of 40 or less often produced a negligible crop of seedlings out of doors. Danish experiments have found red clover more subject to this augmentation of discrepancy than grasses or turnips, but even the latter might give a field braird of only 70–80 per cent when the laboratory germination was 95–98 per cent. Slow growth in the germinator is often similarly reflected by low percentages under field conditions, and it should be borne in mind that poor germination is not wholly compensated by a proportional increase in rate of seeding. It would therefore be better, in making calculations *for purposes of comparison* like those above, to use the energy figure for germination rather than the capacity figure. In doing so, however, it must be remembered that while the comparison may be sounder, the total number arrived at per acre may be much lower than actuality.

It must be emphasized that arithmetical methods of comparison such as those demonstrated can only be applied in connexion with reasonably good quality samples. Samples of

definitely low germination are likely to give wildly erratic and usually quite uneconomic results in the field.

Finally, *the nature of the impurity* must be scrutinized. It is clear that if the bulk of it is inert matter it will do little harm; the purchaser will merely be paying for something he does not want. The effect of " other useful " species depends on the nature and purpose of the sample itself. For example, a few seeds of alsike in a red clover sample which is probably going to be sown mixed with alsike and other species, can clearly do no harm, but ryegrass in a barley sample will behave as, and ought to be considered a weed.

A particular case arises in connexion with ryegrasses. Awned seeds are regarded as impurities in analysing a sample of perennial, while awnless seeds appearing in Italian are usually included in " pure seed " on the assumption that they are probably Italian seeds that have lost their awns. In British produce a considerable proportion of these awnless seeds may often prove, when grown, to be perennial. The proportion is sometimes so high as entirely to stultify any attempt to use a definite proportion of Italian to perennial in a mixture. Since this proportion is very important in mixture design, farmers submitting Italian for analysis *should ask for an assessment of perennial content.*

The remaining consideration is the nature of the weed seeds described as such. In reviewing these it must be borne in mind that number is what really matters, rather than weight, and if numbers are not stated in the analysis the purchaser must use his knowledge of relative sizes of common weed seeds in forming a judgment of the degree of harm he is likely to sustain from those mentioned. This question was referred to earlier (p. 52) and details are given for a number of species in Chapter IV. Particular consideration must of course be given to any parasitic weeds cited, and to the relative difficulty of getting rid of the various kinds—perennials being more dangerous than annuals—and to their habit of flourishing (or not) in the district and soil where the sample will be sown.

Latitude in Tests. It is important to notice that in the nature of things, two tests on the same sample very rarely give *exactly* similar results. In comparing the result of a check test with

any statement of figures given with weed, therefore, one must allow for reasonable variation in either direction. This is recognized by the inclusion of scales of permissible latitude in the seeds regulations of most countries and in the rules of the International Seed-Testing Association.

Chapter Four

Crop and Weed Seeds

In the following pages are given brief descriptions and drawings of the most important crop seeds in use in the United Kingdom and of a selection of the weed seeds most frequently found in them. It must be emphasized that for correct identification of weed seeds a collection of authentic specimens, collected from plants identified while in flower, is essential. Such collections are purchasable, but are expensive and not comprehensive. Serious students should make their own collections, augmenting them at every available opportunity from the field and by exchange. Keys for running down unknown species are of very little use in connexion with seeds: they cannot be exhaustive and if incomplete may be very misleading. Keys are not, therefore, here offered. A very little experience enables the analyst to make a shrewd shot at the natural order, and frequently at the genus, of an unknown species. If he is beaten, the official seed-testing station of his country or district will come to his assistance. If all resources fail he should sow specimens and seek identification of the plant when it flowers. If he has to fall back on this somewhat protracted course, he should use sterilized soil that has been rested for three weeks after sterilization, or he may be deceived by volunteer weeds whose seeds were already present before he sowed his specimen.

CROP SEEDS

CEREALS

Cereals are grasses and are monocotyledons. Their fruits are *caryopses*, consisting of a mass of starchy endosperm, supple-

mented by an outer layer of cells containing nitrogenous *aleurone* grains and divided from the *embryo* by a flat shield of tissue, the *scutellum*, which acts as an absorbing organ at the time of germination, the whole enclosed in a skin consisting of the united ovary wall and true seed coat. The embryo embodies a primary root and a plumular bud whose leaves are coned one within another, united by a very short hypocotylary (below seed leaf) region. The identity of the cotyledon is doubtful. In germination the first shoot to appear above ground is a leaf *sheath* without a blade (the *coleoptile*). Either this or the scutellum may represent the cotyledon. Successive rolled leaves appear each from within the last preceding leaf.

WHEAT (*Triticum vulgare*) (Fig. 10A). Everyone is familiar with the grain appearance—oval form; whitish, yellowish, buff, or red-brown colour; grooved face and rounded back, bearded apex—of our ordinary bread wheats. There are numerous other species and tribes, some of which are used in the husbandry of other countries—macaroni wheat will be familiar in name, if not in appearance, to most readers. Good bread-making wheats show a flinty texture when the grain is broken across.

BARLEY (*Hordeum sativum* (*et vulgare*)) (Fig. 10B). Our barleys are generally classed as " six-rowed," " four-rowed," or " two-rowed." These descriptions refer to the arrangement of grains on the central axis of the ear. In each instance this axis bears, on opposite sides, alternately placed triplets of one-flowered spikelets. In the two-rowed types only the central grain develops in each triplet so that the ripe ear does in fact carry two longitudinal rows of grains. In six-rowed types all three grains of the triplets ripen and hence six longitudinal rows are borne. In certain of these types, however, the lateral grains of the triplet are twisted away from the central grain, and the result, looking lengthwise down the ear, is two opposite rows of single (central) grains and, decussating therewith, two *double* rows of lateral grains. Such are the *so-called* four-rowed types.

In typical six-rowed varieties all three grains of the triplet develop, but are so disposed about the axis that a pair of triplets viewed in plan present six single grains placed at equal angles. Where all three grains develop the laterals are somewhat

twisted in form and their ventral furrow is curved. This characteristic may be used in estimating the proportions present in a mixture of the two types: if the twisted grains in a hundred taken at random are counted and their number augmented by 50 per cent (since each *pair* of twisted laterals would be accompanied by *one* straight central), the figure arrived at will give the percentage of grains from six-row plants.

Most of our malting barleys are of the two-rowed type and may be divided into two groups—erect-eared sorts resembling Goldthorpe, and nodding sorts similar to Chevalier. Grains of the two groups are usually distinguishable by the transverse furrow at the base of the back (Fig. 10B), and the shorter, hairier *rachilla* of the former, as compared with an ungrooved back and longer, less hairy rachilla in the latter.

Fan or sprat barley (*H. zeocriton*) is a two-rowed type that has been used in breeding some of our important modern varieties. Malting barley should be starchy when fractured, not flinty as in a hard wheat.

In common barleys the flowering glumes (chaffy envelopes) adhere firmly to the coat of the caryopsis so that the kernels do not thresh free as do those of wheat and rye. The awn, an extension of the outer flowering glume, is removed by the thresher (as " cavings "), but its base is visible, broken short, at the tip of the threshed grain. There are " naked " races of barley in which the grain does thresh free from the chaffy glumes, but these do not appear in commerce in the United Kingdom.

OATS (*Avena sativa et orientalis*) (Fig. 10C). We chiefly use two types of oat and call them common and Tartarian respectively. Various colours of husk may be met with; the distinction between the species is that in the common (*sativa*) varieties the ear is open and balanced and in Tartar (*orientalis*) it is crowded and one-sided. The grains are thinner and huskier in the latter varieties than in the former.

In oats the flowering glumes closely invest the kernel, but do not adhere as in barley. The caryopsis is sparsely hairy. Awns may be met with on the outer flowering glume, but are not desirable in a good sample. Certain species which thresh

clear of their husk (" naked " oats) become prominent from time to time, but have not succeeded in establishing themselves in favour. They have been used considerably for breeding.

RYE (*Secale cereale*) (Fig. 10D). Varieties of rye are few and grain characters stable. The caryopsis threshes clear of its flowering glumes and in form resembles wheat more nearly than other cereals. It is proportionately longer and narrower than most wheats, more pointed at the base and squarer at the apex. General structure is upon the wheat pattern. Rye is more subject to ergot infection than other common cereals, although the amount of ergot present, even in commercial samples, is seldom more than a trace by weight. Rye also loses its germination capacity more rapidly than other cereals, and yearling stocks are seldom suitable for seeding purposes.

MAIZE OR INDIAN CORN (*Zea mays*) (Fig. 10E). Numerous varieties of maize differing in form and colour of grain are in use in other countries. The caryopsis is broader and thicker at the apex than at the base and the general outline thus roughly triangular. The close packing of the grains, when mature, on the central axis of the " cob " makes this form necessary. Most grains, if cut through, show two distinct areas in the endosperm, a white floury area in which the starch grains are rounded and a dark horny area containing polygonal starch grains.

CONDITIONS IN CEREAL SAMPLES. Colour, smell, and taste are important in judging cereals. Bad weather at harvest, heating in the stack, poor storage or the storing of out-of-condition grain may cause rapid and serious injury to the germination capacity of the seed. A mouldy smell or visible mouldy condition indicates dampness in store. Mouldy corn is to be avoided, either for feeding or sowing. Heating, either in the stack or in stored grain, frequently results in an irregular darkening of the colour natural to the variety. A bitter taste may also develop in the affected grain. Heated bulks with a high initial germination may, in a comparatively short time, show a heavy loss not only in germination capacity but also in the vitality of the grains that still grow. Moreover, heating is often irregular in its action, and part of a bulk may have been rendered unsafe for seeding purposes. With large bulks that

are subsequently split into smaller lots, one recipient of such a lot may have a failure or partial failure in the field, while others may obtain a successful plant. It should also be remembered that when heated grain is sown in the field, particularly when soil or weather conditions are unfavourable, germination may take place without further development, and even plantlets that appear above ground may subsequently die off through weakness, especially should a spell of dry weather succeed germination. Sprouting of the grain while in stook, with subsequent drying and shrivelling of the extended rootlets, does not in itself kill the seed, and sprouted seed will often grow again although naturally with less vigour. Since, however, it reflects bad conditions, sprouted samples are rightly looked on with suspicion.

WEEDS OF CEREALS. Cereals are necessarily arable crops and hence carry arable weeds. Some years ago the Official Seed-Testing Station, Cambridge, determined the weed seed content of a large number of wheat, oat, and barley samples. The examination was spread over several years and the samples were drawn from both farmers and merchants from all parts of England and Wales. This investigation included 13,400, 17,300, and 8,600 samples of wheat, oats, and barley respectively, and the ten most common weeds in the order of their occurrence were:—

Wheat. Cleavers (*Galium aparine*), black bindweed (*Polygonum Convolvulus*), wild oats (*Avena fatua*), curled dock (*Rumex crispus*), knotgrass (*Polygonum aviculare*), field bindweed (*Convolvulus arvensis*), couch (*Agropyron repens*), slender foxtail (*Alopecurus agrestis*), orache (*Atriplex patula*), charlock (*Brassica arvensis*).

Oats. Black bindweed, knotgrass, cleavers, curled dock, bristle-pointed oats (*Avena strigosa*), charlock, orache, ladies thumb (*Polygonum Persicaria*), wild oats, wild radish (*Rhaphanus Rhaphanistrum*).

Barley. Black bindweed, cleavers, wild oats, knotgrass, orache, curled dock, charlock, field bindweed, wild radish, hairy vetch (*Vicia hirsuta*).

In considering these lists it should be borne in mind that they are national and not local and also that well-cleaned commercial lots of cereals are practically free of weed seeds except for an occasional seed or fruit of the larger species.

ROOT AND VEGETABLE CROPS

CRUCIFERÆ. This natural order embraces those crops and weeds whose flowers have four petals, the upper parts of which are arranged in a cross, like wallflowers. It includes all the cabbage tribe and turnip, rapes, and mustards. *Brassica spp.*

COMMON TURNIP (*B. rapa*). SWEDE TURNIP (*B. bapobrassica* (Fig. 11A). The seeds of these species are nearly globular and the testa, under magnification, is seen to be netted over very finely with "thimble markings." Colours vary from a dull smoky purple or grey-black to red-brown. Seeds of the two species are closely similar and individuals cannot be distinguished. The testa does not respond to the chloral hydrate colour test (see Charlock, p. 103), nor does it react positively to Finlayson's polariscope test (see Cabbage, below).

Turnip samples are usually of very high purity and seldom contain weed seeds, but a sharp look-out must be kept for *brown mustard* which, if present, may be in considerable quantity. A more dangerous impurity, which cannot be detected by analysis, is seed resulting from crossing by rape or other crucifer (see p. 2). Old seed reddens.

CABBAGES (*B. oleracea*). This group includes drumheads (*B. oleracea*, var. *capitata*), savoys (var. *bullata*), broccoli and cauliflower (var. *botrytis*), kale (var. *acephala*), brussels sprouts (var. *gemmifera*), and the turnip-like form kohl-rabi (var. *caulo-rapa*). Their seeds are globular, averaging a little larger than turnip and generally a tone of grey, rather than purple or red, in colour. The thimble marking is even less distinct than in turnips. Freshly-harvested seed of members of this group is sometimes affected by delayed germination, and may prove difficult to germinate under standard conditions. Usually, however, this difficulty can be overcome by testing at a lower temperature than that normally used.

Samples are usually free from weeds, but in common with turnips badly-cracked samples sometimes occur.

A surface paring from the testa, examined in surface view between crossed Nicol prisms in a polariscope, shows a dark cross in each cell. This is the *Finlayson test* distinguishing the cabbage tribe from the turnip group.

RAPE (*B. napus*). There are several types of rape in use in Europe; their seeds are similar and resemble turnip or swede seed closely. They do not react to Finlayson's test. *Rape-kale crosses* may occur. They are used as herbage crops, as, in the United Kingdom, is rape.

BLACK MUSTARD (*B. nigra*), WHITE MUSTARD (*B. alba*) (Fig. 11B, C). These are annuals grown for the manufacture of table mustard or as green manure. The white type may be used as salad or as green feed for sheep. The seeds of white mustard are smooth and globular, about twice the diameter of turnip, and light yellow, commonly "smeared" with dirty white. Black mustard seeds are similar in size and shape to turnip, but are easily distinguished under the lens by the net markings on the testa, which are much more deeply cut and obvious. They are reddish-brown in colour.

RADISH (*Raphanus sativus*) (Fig. 11D). These are very large seeds among crucifers, rather more elongated than globular; dull and brown in colour.

CRESS (*Lepidium sativum*) (Fig. 11E). Seeds of cress are elongated, elliptical, not flattened, with a well-defined radicle at the side running the length of the seed. The colour is bright red-brown. Newly-harvested seed is often affected by delayed germination.

HORSERADISH and WATERCRESS are also members of the order Cruciferæ.

UMBELLIFERÆ. This order includes some important root crops, a number of species used for flavouring, and a group of very poisonous weeds. Their "seeds," typically elongated, are borne in pairs adhering together until ripe, and commonly marked by longitudinal ridges and furrows, which may, however, be obscured by strong flattening of the whole "seed" in some species. Many species have oil ducts in the furrows between the ridges, containing strong tasting and smelling essential oil.

CARROT (*Daucus carota*) (Fig. 11F). The seed is broadly elliptical, with four strong longitudinal ridges alternating with five lower ribs. The larger ribs bear long spiny processes, which are mainly removed in cleaning; the minor ribs carry smaller bristles. The smell on rubbing or crushing is pleasantly aromatic. Immature individuals are common.

FIG. 12.—*Grasses*. A—Perennial ryegrass. B—Italian ryegrass. C—Cocksfoot. D—Timothy. E—Meadow fescue. F—Sheep's fescue. G—Hard fescue. H—Crested dogstail. I—Tall oatgrass. J—Golden oatgrass. K—Meadow foxtail. L—Rough-stalked meadow grass. M—Smooth-stalked meadow grass. N—Brown top bent. O, P—Teeth on lateral nerve of inner flowering glume of L and M respectively.

a, awn; *b*, outer; *c*, inner flowering glumes; *d*, rachilla; *e*, callus; *f'*, f, empty glumes.

FIG. 13.—*Forage Legumes and Flax.* A—Red clover. B—Alsike clover. C—White clover. D—Suckling clover. E—Crimson clover. F—Common trefoil. G—Lucerne. H—Sainfoin in cosh. I—Kidney vetch. J—Common vetch or tare. K—Bird's-foot trefoil. L—Soya bean. M—Flax.

PARSNIP (*Pastinaca sativa*) (Fig. 11G). In parsnip the seed is strongly flattened and nearly circular in outline; the inner face bears two orange-red stripes, the outer is papery (nearly white) in colour. The seed often loses growth rapidly.

CELERY (*Apium graveolens*) (Fig. 11H). This is very small seed of papery colour with strongly-marked ridges and furrows. The taste is characteristic. The possible presence of rust disease should be borne in mind (p. 64).

PARSLEY and CARRAWAY are also members of the order Umbelliferæ.

CHENOPODIACEÆ. The natural habitat of many species of this order is the sea-shore. The European members include a few important weeds and three prominent crop types.

MANGOLD, MANGOLD-WURZEL, BEET, SUGAR-BEET (*Beta vulgaris*) (Fig. 11 I). "Seeds" of these crops are really groups of several fruits embedded in the dried receptacle upon which the flowers were borne. Such "clusters" or "bolls" may contain up to half a dozen seeds, but two or three or four are the most usual numbers and one is not infrequent. Conventionally, any cluster that passes a round mesh sieve having apertures of 2·5 millimetres diameter is regarded as an impurity, even though it may contain a seed. Any cluster, *all* of whose seeds have been lost, is also rejected. The clusters are irregularly globular fibrous yellow-brown masses, the centre of which is found to be woody if cut across, the true seeds being relatively small, bright red-brown and oval in form with a distinct projecting radicle tip. The embryo is curved and embraces a central mass of food tissue that appears from recent investigations to be perisperm. Special measures in connexion with germination tests are described on p. 71. Purity as regards weeds is seldom low, but a few of the larger-seeded arable species are common. Two of the more common weed seeds are black bindweed (*Polygonum convolvulus*) and field bindweed (*Convolvulus arvensis*). The latter is regarded as a "prohibited" weed in Canada, so that shipments of mangold and beet intended for that country should be free from it.

SPINACH (*Spinacia oleracea*) (Fig. 11J). The peculiar fruiting arrangement of *Beta* does not obtain in other chenopods. In spinach the "seed" is a true fruit, without receptacle. It is a

pointed oval in outline, flattened, more or less wrinkled, and papery brown in colour.

LILIACEÆ. Apart from ornamental species this order is important as including the leek and various types of onion, shallots, and chives. Some of the ornamental species are rather difficult to germinate successfully under laboratory conditions.

ONION (*Allium cepa*), LEEK (*A. porrum*) (Fig. 11K). Seeds of this species are alike, angular and irregular in outline, often wedge-shaped with one curved side and two flat; black in colour; taste characteristic. The main mass of the seed is pearly grey endosperm about which the curved thread-like embryo lies embedded, its single cotyledon continuous with the radicle, which is presented towards an angle of the seed. Over-yeared onion and leek seed are apt to lose growth with disconcerting rapidity.

GRASSES

GRAMINÆ. The cereals and grasses, including such large forms as bamboo, sugar-cane, and sorghum and the smaller millets, constitute the numerically largest of the natural orders. All are monocotyledons, and in the general type the structure of the grain is that illustrated for wheat. In our common grasses, however, the grain is enclosed in a chaffy husk composed of (usually) two *flowering glumes* which invest it after the manner exhibited in the oat. Commercial grass " seed " therefore consists of flowering glumes plus kernel plus, in most instances, *rachilla*—a short length of the axis of the *spikelet* (branch bearing one or several flowers).. In certain species a second pair of chaffy scales (*empty glumes*) remains enclosing the whole after threshing, as in Yorkshire fog and meadow foxtail. Minor variations of these arrangements also occur.

RYEGRASSES (*Lolium* spp.). These are the most important of all forage grasses. Two species, perennial and Italian, are in use in the United Kingdom, with a number of varieties. The type sold as *L. westerwoldicum* is a variant of Italian, which itself probably arose as a variant of perennial. An annual species, *L. Brazilianum*, finds some use in South America, and

there are two weed species fairly frequent in Europe, one of them poisonous.

PERENNIAL RYEGRASS (*L. perenne*), ITALIAN RYEGRASS (*L. multiflorum*, *L. Italicum*) (Fig. 12A, B). These are canoe-shaped seeds lying naturally on their backs. The outer flowering glume wraps over the edge of the inner and is insecurely locked by teeth on the marginal ribs of the latter. The *rachilla* is typically triangular in outline, wider at the top than at the base, and flat-triangular also in cross-section; florets from the upper part of the spikelet, however, often have a much more rounded and less triangular rachilla, with occasionally a tendency to a " rivet-head " at the apex. This is important in connexion with the possibility of confusion between ryegrasses and meadow fescue (p. 89). Italian exhibits atypical rachillæ more frequently than perennial. Perennial is distinguished from Italian in typical instances by its lack of awn, but it must be noted that some Italian seeds (notably those from the base of a spikelet) develop no awn, and in machining many awns are lost.

In the absence of an awn Italian may be identified by two characters: (*a*) *the Hellbo test*: under a binocular microscope tiny teeth are visible on the *middle region of the lateral nerve of the outer flowering glume*. Teeth are absent *from this position* in perennial, (*b*) *the Gentner test*: if seeds are germinated for a fortnight on white filter-paper, *streaks of blue fluorescence appear in the paper* where the roots have lain, when examined under screened ultra-violet light. Roots of perennial do not induce this fluorescent effect. In general this fluorescence-inducing character seems to accompany shortness of life in the species. It is heritable upon standard Mendelian lines and is exhibited by hybrids and some segregants from perennial: Italian crosses made in either direction. This is therefore a very useful measure of the extent to which a community of perennial ryegrass has become contaminated by crossing with Italian. Such contamination leads to degeneracy and loss of the perennial character. Normal perennial usually lives two or three years under ordinary farming conditions, Italian only one. Indigenous strains show a very low " fluorescence " percentage and are long-lived. British commercial stocks commonly

show some 10 per cent of " fluorescent " individuals. It is important to note that there are European strains of Italian itself that naturally show very little awn but are 100 per cent fluorescent.

Hybrids between perennial and Italian may arise in the field in suitable climates, but do not do so to an appreciable extent in the United Kingdom. British commercial stocks of Italian do, however, too often contain material percentages of true perennial itself; perennials, on the other hand, very seldom contain any serious amount of Italian. The produce now sold as *Pacey's perennial* is not a distinct form. It is composed of the small seeds from the upper part of the spikelet of ordinary perennial, separated during machining, and is synonymous with *short-seeded perennial*. Modern machinery purifies ryegrass so efficiently that samples of 98 and 99 per cent purity are easily purchasable.

ARGENTINE RYEGRASS (*L. Brazilianum*) is an unproductive annual, useless here. Its seedlings are " fluorescent." The inner flowering glume is thin and the enclosed kernel is rather conspicuous.

DARNEL (*L. temulentum*) is an annual cornfield weed poisonous by reason of a contained fungus. (See p. 116.) The seeds are extremely rare in commercial bulks grown in this country.

SPARSE-FLOWERED RYEGRASS (*L. remotum*) is a very common annual impurity in European flax samples.

COCKSFOOT (*Dactylis glomerata*) (Fig. 12C). Seed of cocksfoot is rough and hard to the touch, so that when bagged it can often be identified by feel without opening the bag. The outer flowering glume is very strongly keeled and towards the tip rough with small sharp asperities. It is drawn out into a stiff point scarcely amounting to an awn. The rachilla is straight, cylindrical, and knobbed. The seed is curved slightly and lies naturally on its side; as a result it is not nearly so easy to see the kernel by diaphanoscopy in cocksfoot as in ryegrass, the more because in the former the kernel itself is pale and translucent. It is soft, too, and easily damaged by careless use of a scalpel in " feeling " for it. Cocksfoot florets vary markedly in size from the lower to the upper part of the spikelet, and one or two of the uppermost are usually barren. Hence first-class

samples tested on the " continental " system commonly show from 7 to 10 per cent of inert matter, consisting of empty or very immature " seeds." Apart from this, most commercial samples are of very high purity.

Large supplies of indigenous strains are now available, and New Zealand seed is also obtainable. Shipments of Danish cocksfoot have now been resumed to this country.

TIMOTHY (*Phleum pratense*) (Fig. 12D). While most of our timothy seed is of Canadian or American origin a considerable quantity is produced in Scotland. English-grown seed is also now available. During the past twenty-five years dodder has never been recorded at Cambridge in timothy seed originating from any of these sources. Seed of continental origin may, however, contain dodder. The flowering glumes are very thin, delicate, and of a bright silvery colour by reflection of light. There is no rachilla. Frosted samples of a grey tone, and dull brownish samples badly harvested or badly stored, may occur.

The pointed ovate honey- or coffee-coloured kernel shakes free of its glumes very easily (" shelled seed "), but this does not affect its germination at all if the seed is fresh. Shelled seed does not store so well as weed retaining its husk.

LARGE FESCUES (*Festuca elatior et* spp.) (Fig. 12E). The most important of these in our agriculture is the form called meadow fescue (*F. pratensis*). The seed of this species *very* closely resembles perennial ryegrass. Typical distinctions (subject, however, to considerable variation) are: (*a*) the rachilla of fescue is cylindrical and kobbed or " riveted " at the apex, that of ryegrass flat faced and triangular in outline; (*b*) the outer flowering glume of fescue, if the seed is viewed lying on its face, appears *slightly* lop-sided, but that of ryegrass symmetrical; (*c*) the glume colour of fescue is commonly lighter and more papery than that of ryegrass, which has a green-grey shade; (*d*) the glume of frescue is more brittle and more commonly broken at the tip than that of ryegrass. Adulteration of meadow fescue with ryegrass is now rare and if it occurs is usually inadvertent.

Even individual specimens, if typical of their species, are quite easily distinguished by the rachilla, but in all bulk samples there are a few seeds of atypical appearance upon which an

opinion must be formed by accumulation of evidence. Meadow fescue seed does not retain its germination capacity well during storage over-year, and when it starts to fall in vitality falls rapidly. Tall fescue (*F. elatior*) is relatively little used. The seed is larger than that of the *pratensis* type and is often awned. Danish samples of meadow fescue are usually larger seeded than American, approaching the tall type.

REED FESCUE (*F. arundinacea*) is a coarse reedy grass that may be encountered, but it is not of agricultural value. Its seed is very similar to that of *F. elatior*.

SMALL FESCUES (*F. ovina et* spp.). The type seed of this group is flask-shaped, having a rounded belly and pointed upper end, which may be awned. The rachilla is cylindrical and knobbed. Short hairs may be present on the outer flowering glume and rachilla in larger forms.

SHEEP'S FESCUE (*F. ovina*) and FINE-LEAVED SHEEP'S FESCUE (*F.* (*ovina*) *tenuifolia*) (Fig. 12F). This is the smallest of the group. The seeds are free from hair or awn. The two forms are not botanically distinct, but the so-called fine-leaved form is the smaller seeded.

HARD FESCUE (*F.* (*ovina*) *duriuscula*) (Fig. 12G). This is a larger grass with a larger seed. The latter is most frequently shortly hairy on the flowering glume and about the rachilla, and the apex is usually shortly awned.

RED FESCUES (*F. rubra genuina, et fallax*). These are distinct fescues of value on account of their underground creeping habit. The seeds very closely resemble smooth hard fescue seeds. They generally exhibit a reddish tinge, but so may the other small fescues. The variety *fallax* is sold as Chewing's fescue. It is excellent for use in the production of fine turf. Our supplies are derived from New Zealand. The seed does not hold its germination well and frequently suffers heavy loss in growth during transit. The artificial drying of the seed before shipment may help to get over this trouble.

CRESTED DOGSTAIL (*Cynosurus cristatus*) (Fig. 12H). Except for absence of keel, crested dogstail seed resembles a small, coloured cocksfoot seed. The rachilla is similarly cylindrical and knobbed, the upper part of the flowering glume is roughened in the same way and the tip is drawn out into a short stiff point.

The colour (except in odd bleached individuals), however, is bright yellow, often with a faint greenish tinge, in good fresh samples, or brown-yellow to brown in poorly harvested produce. Bright colour is generally sought, but brownness does not of itself connote low quality. The seeds are uniform in size, whereas those of cocksfoot are very variable.

A larger seeded annual and valueless species, carrying a long awn and resembling a fescue in form and colour, *C. echinatus*, may occasionally be met with, described as " Chilean ryegrass."

OAT GRASSES. Two so-called oat grasses, tall and golden, may be encountered, though neither is greatly used. The former is the more frequent. Others may occur as weeds.

TALL OATGRASS (*Arrhenatherum avenaceum*) (Fig. 12, 1). This " seed " is in reality a whole spikelet, less the empty glumes. The two florets of the spikelet, the lower sterile and the upper fertile, break away as a unit in threshing. The flowering glumes are very harsh and invest the kernel closely; germination is usually improved by " shelling " before placing on the seed bed. The sterile spikelet bears a strong bent and twisted awn, the fertile floret a much finer straight one, and the base of the seed is adorned with silky straight hairs, pointing upwards. The general colour is pale brown, the larger awn being dark brown with a pale spiral stripe. In view of its size, the lb. or the bushel contains relatively few seeds and the price per seed is accordingly high.

GOLDEN OR YELLOW OATGRASS (*Avena flavescens*) (Fig. 12J). A species seldom used. The sample is pale brown-gold in colour and very light and " chaffy " looking. The flowering glume is split at the tip, each half bearing a bristle, while a stronger awn, bent and twisted, arises nearly half-way down its back. The rachilla and base of the glume are hairy.

MEADOW FOXTAIL (*Alopecurus pratensis*) (Fig. 12K). This is the earliest of all our useful grasses, following in spring close upon *Anthoxanthum* (sweet vernal grass) which is not of practical value though it has been used to some extent in the past. Unfortunately, foxtail is extremely difficult to establish in a mixture, and though it flourishes in permanent meadows will not do so much under pasture conditions. The flat seed con-

sists of the whole spikelet i.e. a pair of strongly keeled and very hairy empty glumes, united by their edges from the base about one-third of the way up, and enclosing a solitary flowering glume of a thin delicate texture within which the soft, flat, butterscotch-yellow caryopsis reposes, usually surmounted by the thread-like shrivelled remains of the " stigma."

The sample as a whole is grey, individual seeds being darker on one side than the other. The flowering glume carries a bent awn, arising from the middle of the back. (See also note on parasites, p. 57.)

BLACK GRASS, SLENDER FOXTAIL (*A. agrestis*) and KNEE'D FOXTAIL (*A. geniculatus*) occur as weed impurities. Seeds of the former are more elongated, scarcely hairy, harsh in the husk, with very soft spindle-shaped caryopses and having empty glumes united for about half their length; those of the latter are smaller, shaped and coloured rather like *A. pratensis*, but darker.

" MEADOW GRASSES " (*Poa* spp.). This genus, while only of limited use in the United Kingdom, is of great importance in some other countries, notably in parts of North America, where one species, *P. pratensis*, shares with timothy the position of greatest importance among sown grasses. Their seeds are very small, strongly keeled throughout their length and triangular in general cross-section; the rachilla is cylindrical and knobbed and the base of the seed is furnished with a tiny mop (" web ") of soft cottony hair, the profusion of which varies with the species, as does the quantity and distribution of other, shorter, hairs on other parts. The cottony " web " is lost with age and machining.

ROUGH-STALKED POA (*P. trivalis*) (Fig. 12L) has a relatively small basal web and otherwise is only hairy on the midrib of the flowering glume.

SMOOTH-STALKED POA (*P. pratensis*) (Fig. 12M) is the American " Kentucky bluegrass." The basal web, when fresh, is profuse, and the lateral ribs of the flowering glume as well as the midrib are furnished with short hairs.

Poa compressa, Flat-stemmed meadow grass or " Canada bluegrass," and *Poa annua*, annual meadow grass, the latter having rather larger seeds covered generally with short hair, may

be met as impurities, the latter frequently. *Poa compressa* is considered of value as a pasture grass in some parts of Canada.

Poa nemoralis, wood meadow grass, is a useful lawn-making species for shaded places. The seed is very similar to that of rough-stalked poa. Little, if any, seed is now available.

DIAGNOSIS OF *POAS*. For British and European purposes it is important to distinguish the seeds of *Poa pratensis* from those of *P. trivialis*. Differences in hair distribution have been noted, but these are often insufficient guide for precise analysis. The hairs are very easily lost, and although in rubbed seeds their stumps can often be discerned with the aid of a microscope, it is to be observed that in so laborious an examination only a few hundred seeds at the most can be critically scrutinized, with the result that the numerical percentage analysis is materially affected by wrong or doubtful identification of one or two individuals. Something more definite than hair distribution is thus required. The process used in practice is as follows: The seeds are soaked for twelve to twenty-four hours in a dilute (2·5 per cent) caustic potash solution, which causes the flowering glumes to gape apart. The *inner flowering glume* is then picked off with fine forceps and scalpel and mounted on a glass slide. Upon examination under a compound microscope of low power, the *lateral ribs* of the glume are seen to be set with fine teeth pointing slightly forwards. Those of *P. trivialis* are very fine and closely set; those of *P. pratensis* are coarser, more widely spaced, and more hooked. Their appearance in each of the two species is presented in Fig. 13. A less tedious, but less certain, diagnosis can be made by binocular observation of minute teeth on the central rib of the outer flowering glume.

BENTS (*Agrostis* spp.). Species of this genus are numerous (about 100) and their floral structures diverse. Several are cultivated, chiefly for lawn and sports ground purposes. One or two are constant, and often very profuse, in old pasture. The diagnosis of *Agrostis* seeds is troublesome and calls for very close scrutiny under considerable magnification. The seeds are minute, the outer flowering glume smooth and flask-shaped, translucent and silvery in appearance; the inner is often vestigial

or missing. The kernel is toffee-coloured and spindle-shaped. In only a few uncommon species is there any rachilla.

Agrostis tenuis (= *A. vulgaris*) (Fig. 12N) is imported from New Zealand as " brown-top " and from America as Rhode Island bent. It is also sold as colonial bent, Prince Edward Island bent, and Oregon bent. Its outer flowering glume is dull and has three or four indistinct veins; its inner flowering glume is reduced to about half the length of the outer; both are toothed at the apex. An awn is occasionally developed on the outer flowering glume.

A. canina, black bent or velvet bent, is awned. The inner flowering glume is *apparently* missing, but really present as a minute adhering scale. The outer flowering glume is dull and may have three, four, or five veins. This species and the last mentioned are the best lawn types, having strong creeping capacity.

A. palustris, the fiorin of most European countries, is an *olla podrida* species including a number of forms sometimes given specific names, such as *A. alba*, *A. repens*, *A. stolonifera*, and combinations of these. It is an unsatisfactory description on this account. It is met with under various other names, such as creeping bent, seaside bent, and black bent. Red top is the name by which it is commonly known in North America.

The outer flowering glume of fiorin is awnless, thin, and silvery, and the inner is two-thirds as long or a little less.

LEGUMINOUS CROPS

CLOVERS. Small-seeded legumes as a group are loosely spoken of as " clovers "; the title should properly be reserved for the various species of *Trifolium*. Of these there are some half-dozen of importance as crops in British agriculture; others find favour in other parts of the world.

RED CLOVERS (*T. pratense et* var.) (Fig. 13A). Two types of red clovers are in use: the so-called " broad " red and late-flowering red. Each is met with under a variety of names; the expression " single-cut cow grass " is commonly associated with the latter type, in reference to its non-production of aftermath. Individual seeds of the two are indistinguishable.

Wild strains of red clover are also purchasable, their seeds, though usually of a small average size, resembling in other respects those of the " cultivated " varieties. Red clover seeds are oval in general form, with a rounded " nose " occasioned by the protrusion of the radicle beyond the marginal line of the opposed cotyledons, which are adherent to the embryo axis only at the hypocotyl. The radicle is disposed centrally when the seed is viewed on edge. The *hilum*, or scar left by detachment of the stalk on which the seed grew within its pod, is found a little below the " nose " of the radicle, and between the two is the *micropyle* (pore) through which the pollen tube entered the ovule at the time of fertilization and through which water most easily enters before germination. Most red clover seeds are purple at the north end, shading to greyish-yellow at the south, though they may vary from wholly purple to wholly grey-yellow. All the seeds from a given plant, if fully ripe, are the same colour, but distribution of colour is very variable within a commercial sample and still more so between samples from different countries of origin. The same variety, if grown in different countries, will show different colour proportions.

The chief difficulty in the analysis of red and other clovers is discrimination between grave injuries and unimportant cracks. This question has been discussed on pp. 54–55. It is important in germination tests to give time for internal injuries to discover themselves before making the first count. Three days are often too little for safety and four are better.

Good fresh red clover seed should be bright and shiny of surface; old seeds turn red; dullness of testa may be due to age, bad storage, bad harvesting conditions, occasionally to scarification, though this is seldom necessary with this species. Weathering leads to brown colour.

ALSIKE (*T. hybridum*) (Fig. 13B). This clover takes its name from the Swedish village Ålsike and should not be spelled, as it often is, Alsyke. It was named *hybridum* under the impression that it was a cross between red and white clovers, but this belief is not supported by modern investigation. The seed structure is similar to that in red clover, but the radicle is as long as the cotyledon, which brings the " nose " down to the end of the seed and results in a heart shape. Colours vary from

pale apple green through chequered light and dark green types to a green so dark as to be nearly black. Fresh seed should be polished; old seed turns red. Hard seed is commoner than in red clover.

WHITE CLOVERS (*T. repens et* var.) (Fig. 13c). Wild white and Dutch white clovers are in common use. There are no botanical distinctions of specific rank between them; the real difference between a community of "wild" and a community of "Dutch" is much the same as that between weak whisky and soda and strong whisky and soda. Each is a mixture of strains. In the wild community the proportion of long-lived individuals is high; in the Dutch community the proportion of short-lived is high.

The seed of either is of the heart-shaped type and yellow or brown-yellow in colour. Dull brown colour usually means poor ripening conditions. The outline of white clover is a little broader in proportion to length than that of Alsike, a point often useful in the separation of a mixture of the two. If all seeds were typical, colour would be an obvious criterion for this separation, but seeds are often atypical, and brown seeds, almost certain to be present in either species, are a special difficulty in a mixture. Unripe seeds also cause trouble, since in normally green alsike they are yellowish and in typically yellow white clover they tend to be green.

DIAGNOSIS OF WILD WHITE. There is no single test by which wild white and "cultivated" Dutch white may be distinguished. An opinion must be formed by reference to the accumulated evidence of several factors. The notes that follow are approximate guides only, and it must always be borne in mind that very material variations naturally occur.

(1) *Size.*—Most of a wild white sample passes a sieve of round mesh apertures one twenty-fourth of an inch in diameter. Little Dutch white passes this sieve.

(2) *Weight.*—1,000 wild white seeds weigh about 0·5 gramme; of Dutch white about 0·7 gramme.

(3) Typical *old pasture* impurities are: dogstail, *Agrostis*, *Lotus*, *Holcus*, ryegrass, *Poa*, sweet vernal, self heal, field wood rush."

Typical *arable land* impurities are: dove's foot cranesbill (*Geranium molle*), chickweeds, campion.

It is, of course, the combination of impurities, rather than any single one, that is of most value, although it is interesting to record that out of 1,009 white clover samples examined at Cambridge 683 contained dove's foot cranesbill, while only in 305 out of 2,761 samples of wild white clover was this impurity found. The presence of this weed combined with other arable weeds and the absence of old pasture grass seeds are, therefore, factors of considerable importance in forming an opinion.

In this connexion it should be remembered that wild white clover once-grown is from arable land.

(4) *Cyanogenesis.*—In the bulk, wild white is more strongly cyanogenetic than cultivated varieties. The cyanophoric test,[1] however, has been shown to be definitely unreliable for single seeds.

SUCKLING CLOVERS (*T. dubium et* spp.) (Fig. 13D). Under the Seeds Regulations of 1922 five species are included under the name suckling clover. In farming practice only *T. dubium* is sown under this description, though *T. procumbens* and *T. filiforme* find sale in Ireland and elsewhere as pot plants under the name " shamrock."

Suckling clover seed is nearly elliptical, the radicle being only a little shorter than the cotyledon but closely appressed and thus causing very little suggestion of a " nose." The testa is highly polished and the colour varies from lemon yellow through butter yellow, ochre and brown to olive. Hard seed is often plentiful.

CRIMSON CLOVER (*T. incarnatum*) (Fig. 13E). This is the largest seed among the common clovers. In outline it is elliptical with no noticeable " nose," and in colour either white or buff-brown all over. The testa is brittle and cracks

[1] *Cyanophoric Test.* This is a delicate test for evolution of prussic acid gas. Seeds are germinated for about five days in the light, until the cotyledons are expanded and green. They are then dropped into a corked glass tube, a spot of toluol is added and a strip of yellow sodium picrate paper is inserted and held clear of the seedlings by gripping it between cork and glass. The tube is then incubated at about body temperature (a pocket is convenient for this) for a period of from a few minutes up to half an hour. Evolution of prussic acid (cyanogenesis) is indicated by a brown, red, or orange discoloration of the yellow test-paper.

Sodium picrate paper is made by soaking strips of clean filter-paper in a solution prepared by neutralizing one gramme of pure picric acid dissolved in 200 c.c. of distilled water, with 10 grammes of pure anhydrous sodium carbonate, and drying.

easily; dubious broken growths are troublesome in the germination of many samples, but hard seed are rare.

SUBTERRANEAN CLOVER (*T. subterraneum*), with seed resembling white clover, an annual which buries its seed pods in the earth at ripening; STRAWBERRY CLOVER (*T. fragiferum*), seed of which is very similar to that of Alsike; the perennial ZIG-ZAG CLOVER (*T. medium*), whose seeds are like those of red clover; and SULPHUR CLOVER (*T. ochroleucum*), with large dull yellow seeds, are all uncommon but may occasionally occur.

MEDICKS (*Medicago* spp.). Two species of this genus are in use in the United Kingdom, common trefoil and lucerne. We grow our own seed of the first-named, but in the main we import seed of the second from France, other continental countries, and Canada.

TREFOIL (*M. lupulina*) (Fig. 13F). This may be purchased in cosh or milled. The former is the whole fruit—a jet black kidney-shaped thin capsule, ridged in a network on the outside and containing a single seed. When milled the true seed is exposed as a dull ochreous or paler yellow, kidney-shaped and with a radicle " nose " of retroussé form projecting in the notch of the kidney. Greenish shading is fairly common. Cracked seeds are often difficult to detect and broken growths a common trouble in germination tests. Viewed on edge the radicle is centrally disposed along the cotyledon edge (a distinction from lucerne, *q.v.*).

LUCERNE (*M. sativa*) (Fig. 13G). Seeds of lucerne may be of two forms, both of which will appear in a sample—a type resembling red clover in shape and one of longer and more kidney-shaped form, often with a truncated " forehead " at the distal end of the cotyledon The colour is uniform dull brownish-yellow. This species and the previous have seeds naturally dull, they should not be lustrous like those of clover. The tip of the radicle of lucerne is turned aside from the central line, giving the seed when viewed on edge a bent appearance that furnishes a distinction from trefoil when certain individuals resemble the latter in outline.

CALCICOLE LEGUMES. A few leguminous species are specially adapted to chalky land; two of these are in ordinary use in Britain.

SAINFOIN (*Onobrychis sativa*) (Fig. 13H). Seed may be purchased milled or unmilled (in cosh). The true seed, milled, is among the largest of leguminous forage crop seeds, kidney-shaped, with dark hilum in the notch, bright brown, often flecked with black. In the unmilled sample, the capsule is of a light papery brown, marked with a network of strong external ridges that bear irregular short stiff spines, while a crest of larger spines adorns the outer edge of the fruit, the outline of which is half-elliptical. Broken growths are often troublesome in sainfoin germination tests. Yearling seed does not carry over well and is usually of comparatively low growth.

KIDNEY VETCH (*Anthyllis vulneraria*) (Fig. 13 I). Pretty seeds when fresh are those of kidney vetch. In shape and size they are similar to red clover seeds; the north end is coloured bright green and they shade to a silvery grey at the south. Old seed turns yellow-brown. The seed is rather easily damaged and the germination tests often show a high percentage of broken growths.

PULSE CROPS

Beans—dwarf, broad, or climbing—and peas are among our most familiar seeds.

BROAD BEAN (*Vicia faba*), really a vetch, may be green or light brown in colour when dry, and of a size varying greatly from variety to variety. The brown HORSE or FIELD BEANS are varieties of the same species. GARDEN PEAS, varieties of *Pisum sativim*, may be either smooth or wrinkled, green-yellow or white. FIELD PEAS (*P. arvense*) are grey or speckled brown (partridge) and rather less globular than the garden varieties.

SWEET PEAS are varieties of *Lathyrus odoratus* and thus vetchlings rather than true peas. They often contain a considerable proportion of hard seeds.

KIDNEY BEANS (annual), SCARLET RUNNERS (perennial), and DWARF (FRENCH) BEANS are species of *Phaseolus*. The LENTIL (*Lens esculenta*) is an orange-yellow lens-shaped seed, whence its generic name. The EARTH-NUT (monkey-nut) and numerous other beans, peas, and vetchlings, grown abroad are used as stock foods, the *locust bean* and *fenugreek*, also legumes, being used as condiments.

MISCELLANEOUS LEGUMES

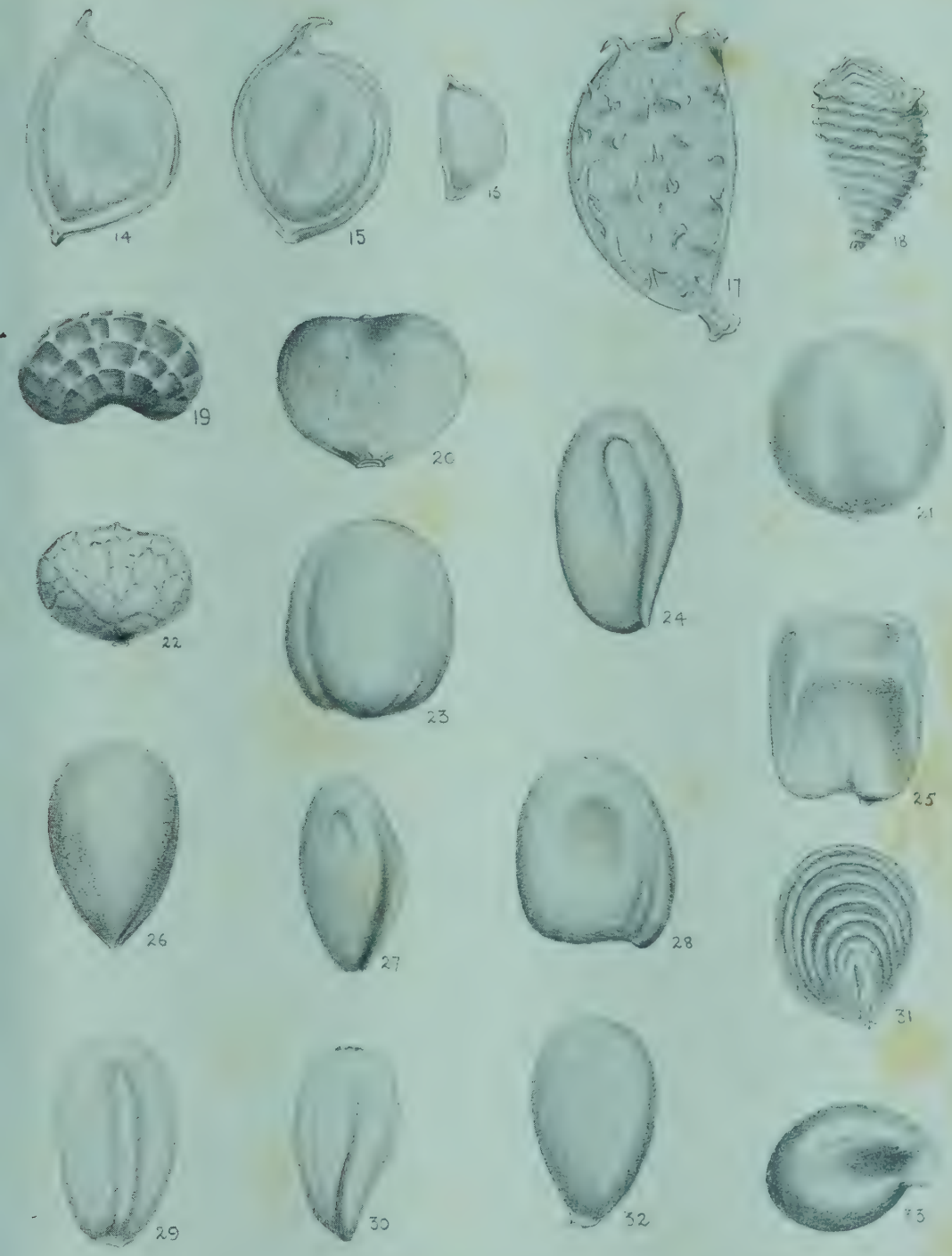
VETCHES (*Vicia sativa*) (Fig. 13J). Dull, patchy brown or dun seeds of ovoid outline when lying on their sides, flattened slightly, or sometimes almost to a lens shape. The hilum is elongated and marked with a light stripe. Several other species of *Vicia* may be met with as impurities.

BIRD'S-FOOT TREFOIL (*Lotus corniculatus et* spp.) (Fig. 13K). This common pasture legume, occasionally sown, bears seeds of which often a high proportion may be hard. In shape they are shortly oval, or kidney-shaped, and may be a coffee brown, speckled brown, or deep olivaceous green in colour. The hilum is circular and clearly marked.

SOYA BEAN (*Glycine soja*) (Fig. 13L). This crop is of high importance in Japan and North America as human food. In Europe the imported seed is used as a cattle food, but its extended use as a field crop here will depend upon the elaboration of strains suited to our length of day and length of season. The species is markedly influenced by these factors and affords an excellent demonstration of the effects of varying periods of illumination. The beans are about the size of a small ordinary pea, ovoid in shape, with a somewhat scurfy elliptical hilum, and vary in colour from yellow or buff through yellowish-green and brown to black.

MISCELLANEOUS CROPS

FLAX OR LINSEED (*Linum usitatissimum*) (Fig. 13M). The bright brown colour and long-oval outline, with flattened section of linseed, is familiar to everyone. The seed is notable for the mucilage contained in a dry condition in the seed coat, which swells up into a slimy mass on the addition of water—the factor upon which the linseed poultice is largely dependent for its value. The radicle is placed at the lower, narrower end of the seed, and upon germination is extruded at this point. Plants used for fibre are tall types with few branches and bearing small seeds, while the linseed-producing varieties are shorter, profusely branched and larger-seeded. Flax is the only fibre crop grown commercially in the United Kingdom.



FIGS. 14–33.—14—Ranunculus acris. 15—R. repens. 16—R. sceleratus. 17—R. arvensis. 18—Delphinium consolida. 19—Papaver dubium. 20—Fumaria officinalis. 21—Brassica sinapis. 22—Neslia paniculata. 23—Raphanus Raphanistrum. 24—Camelina sativa. 25—Barbarea vulgaris. 26—Lepidium campestre. 27—Erysimum orientale. 28—Eruca sativa. 29—Capsella Bursa-pastoris. 30—Erysimum cheiranthoides. 31—Thlaspi arvense. 32—Viola tricolor. 33—Reseda lutea.

FIGS. 34 53.—34—Lychnis Githago. 35—L. diurna. 36—L. vespertina. 37—Stellaria media. 38—Cerastium triviale. 39—Spergula arvensis. 40—Malva sylvestris. 41—Geranium dissectum. 42—G. molle. 43—G. pusillum. 44—Melilotus officinalis. 45—Vicia angustifolia. 46—V. cracca. 47—V. sepium. 48—Lathyrus pratensis. 49—Arthrolobium scorpioides. 50—Poterium sanguisorba. 51—Rosa pratincola. 52—Potentilla monspeliensis. 53—Œnothera biennis.

COMPOSITÆ. Plants of the daisy and dandelion order usually have seeds of a long, narrow shape and are either flattened or angular in section by reason of their close-packed style of growth in the head of flowers. A few crop species are members of this order; familiar examples are LETTUCE (*Lactuca sativa*) with flat snowshoe-shaped black or nearly white seeds; CHICORY (*Cichorium Intybus*) with squarely angular seeds, collared at the upper, broader end; and SALSIFY (*Tragopogon porrifolius*), with seeds like much enlarged dandelion seeds. The "seed" of these is really the whole fruit, the ovary wall being united with the testa.

WEED SEEDS

FORM GROUPS. It will be found that by far the most of our common weed seeds, if classified by their shape, fall into fairly clear groups (spherical, oval, spindle, kidney, and the like), generally corresponding with a natural order of plants or a section of a natural order. This is to be expected if it is remembered that the natural orders are groups of species of similar characteristics, that these characteristics are chiefly floral structures or arrangements, and that the form of a seed depends very largely upon such factors. Thus globular seeds are characteristic of a section of the natural order Cruciferæ in which the uncrowded pod-like fruit allows room for free development; seeds with one round side and one flat are borne by many *umbellifers*, in which the fruits are developed in pairs at first united and splitting asunder when ripe; elongated forms somewhat narrower at bottom than at top are characteristic of *composites*, which carry their fruits arranged on a more or less flat receptacle after the manner of the knots of bristles in a broom, and where the receptacle is crowded, fruits angular in section result.

It is not of course to be supposed that hard-and-fast rules can be laid down by which a natural order can automatically be identified in its seeds or fruits—there are plenty of variations and exceptions, while similar forms are naturally to be found in more than one order. It is hoped, however, that the grouping of the species, in the notes that follow, into types within natural orders, may help inexperienced readers to reduce the width of

field that must be hunted for the identity of an unknown specimen. No attempt is made to be exhaustive, and species that are infrequently met with in commercial seeds are not mentioned.

DESCRIPTION OF WEED SEEDS

(Numbers correspond with figures. Measurements in millimetres indicate the greatest dimension of an average specimen.)

RANUNCULACEÆ—Buttercup Family.

(*a*) *Flat type, with beak but no spines.*

Ranunculus acris—Upright Buttercup. (14)
3 mm. Oval, narrow or pointed base, thin edge sometimes winged, beak medium, light or dark brown if ripe, with lighter often greenish edge, smooth but not polished.

R. repens—Creeping Buttercup. (15)
3 mm. Similar to *R. acris*, but beak a shade larger and more hooked.

R. sceleratus—Celery-leaved Buttercup. (16)
1·7 mm. Less flattened than preceding, well-marked edge line, very small blunt beak, may be slightly wrinkled.

(*b*) *Flat, with snout and spines.*

R. arvensis—Field Buttercup. (17)
Oval disc with straight blunt snout, edge and faces bear strong curved or straight and pointed spines, colour tawny or neutral grey-brown.

(*c*) *Wedge-shaped type.*

Delphinium consolida—Wild Larkspur. (18)
1·5–2 mm. Irregular leg-of-mutton shape, thicker on one side than the other, broader one end than the other, repeatedly belted with thin wing-like projections in a parallel series, colour dark grey-brown, wings lighter.

PAPAVERACEÆ—Poppy Family.

Seeds kidney-shaped, surface covered with a network of ridges enclosing polygonal pits (thimble marking).

Papaver dubium—Long Smooth-headed Poppy. (19)
0·8 mm. Colour steely grey to nearly black, pits proportionately larger than in *P. rhœas*, and four-sided.

P. Rhœas—Common Red Poppy.
1 mm. Colour smoky grey, pits irregularly hexagonal.

Fumaria officinalis—Common Fumitory. (20)
2 mm. Fruit, nearly globular with minute point in a shallow apical depression, surface finely roughened and dull, colour yellowish-green, sometimes with silvery tinge.

CRUCIFERÆ—Cabbage Family.

(*a*) *Globular type.*

Brassica sinapis—Charlock. (21)
1·5 mm. Resembles swede. Superficially smooth, very fine thimble marking visible under magnification, colour reddish-purple, grey or nearly black. Pieces of testa soaked in strong acidified chloral hydrate solution show blood-red colour. (Distinction from turnip, swede, and cabbage. Solution: Chloral hydrate 8 gms., water 5 c.c., hydrochloric acid 3 drops.)

B. nigra—Black Mustard. (11c)
1·5 mm. Testa strongly thimble marked with deep hexagonal pit, visible under lens. Colour rich brown.

Neslia paniculata—Ball Mustard. (22)
2·5 mm. Very round with small basal snout, rough netted coat, colour green to greenish-brown.

Raphanus Raphanistrum—Wild Radish. (23)
3 mm. Bluntly oval, superficially smooth, dull, finely rough if magnified, grey-brown. Often contained in longitudinally ridged, barrel-shaped section of broken pod.

(*b*) *Elongated plump type*, radicle position indicated by grooves in testa.

Camelina sativa—False Flax. (24)
2 mm. Smooth, brownish-yellow, becomes very slimy when wet.

C. microcarpa—Small-seeded False Flax.
Similar to *C. sativa*, but half the size, darker in colour and more granular of surface.

Barbarea vulgaris—Winter Cress. (25)
1·5 mm. Finely pitted, somewhat silvery sheen, colour of old hay.

Lepidium campestre—Field Cress. (26)
2 mm. Oval, pointed apex, dark brown, dull, becomes sticky on wetting.

Erysimum orientale—Hare's-ear Mustard. (27)
2·5 mm. Similar shape to 24, yellowish or reddish shade of brown, granulated surface, bitter taste, becomes sticky if wet.

Eruca sativa—Worm-seed Mustard. (28)
2 mm. Somewhat compressed, toffee-brown.

(*c*) *Elongated flat type*, radicle position indicated by grooves.

Capsella bursa-pastoris—Shepherd's Purse. (29)
1 mm. Narrow oval, yellow, dull, surface finely granular under magnification.

(*d*) *Oval flat type.*

Erysimum cheiranthoides—Treacle Mustard. (30)
1·5 mm. Toffee-brown or yellow, dark hilum, bitter taste.

Thlaspi arvense—Pennycress. (31)
2 mm. Oval, notched at end, strong concentric serrated ridges (suggesting a thumb mark), colour dark red-brown.

VIOLACEÆ—Violet Family.

Viola tricolor—Heartsease. (32)
2 mm. Plump, oval, polished, straw-yellow, whitish protrusion ("caruncle" at narrow end).

RESEDACEÆ—Mignonette Family.

Reseda lutea—Wild Mignonette. (33)
1·5 mm. Plump, unbalanced kidney-shape suggesting a swollen comma, polished, black with light-coloured protrusion in notch.

CARYOPHYLLACEÆ—Carnation Family.

(*a*) *Wedge-kidney type.*—Short broad kidney outline with shallow notch when lying on side, wedge-shaped with broad end rounded when viewed on edge, surface thickly covered with short teeth or warts arranged in close parallel rows concentric to notch of kidney.

Lychnis Githago—Corn Cockle. (34)
3·5 mm. Purple-black to back, redder if unripe. Teeth coarse. Poisonous.

L. diurna—Red Campion. (35)
1·5 mm. Smoky purple to grey-black. Teeth closer than 24.

L. vespertina—White Campion. (36)
1·5 mm. Dirty-grey or grey-buff, shade larger and slightly coarser teeth than 35.

Silene inflata—Bladder Campion.
1·5 mm. Very similar to red campion, but with a strong protuberance at notch.

Saponaria vaccaria—Cow Cockle.
2 mm. Dull smoky-purple to black, warts rounded.

Stellaria media—Chickweed. (37)
1 mm. Very broad kidney or nearly round in outline, warts blunt and corky looking, colour red-brown or snuff.

Cerastium triviale—Mouse-ear Chickweed. (38)
0·75 mm. Smaller than 37 and often broader than long, so as to be roughly triangular in outline on the side. Warts small and widely spaced.

(*b*) *Sub-globular, smooth type.*

Spergula arvensis—Spurrey. (39)
2 mm. Nearly spherical in form with equatorial wing, testa dull black, minutely granular, often with light flecks, wing light.

MALVACEÆ—Hollyhock Family.

Malva spp.—Mallow. (40)
Sizes 1·5–2 mm. Shape like a section of orange, but with sharp angles between curved and flat sides, outer side rugged with strong raised net of ridges, colour dull brown-grey.

GERANIACEÆ—Cranesbill Family.

Geranium dissectum—Cut-leaved Cranesbill. (41)
2 mm. Broadly oval, surface strongly thimble marked with longitudinal rows of hexagonal pits of red-brown colour, ridges lighter.

G. molle—Soft Cranesbill. (42)
1·5 mm. Outline elongated D-shape or nearly elliptical, surface smooth but dull, yellow-brown colour. The papery fruit capsule is often present and is highly characteristic, being thin, greyish, free from hair, but adorned by a series of thin wavy ridges set at an oblique angle to the axis.

G. pusillum—Small-flowered Cranesbill. (43)
Seed exactly similar to 42, but capsule free from ridges and furnished with upward-pointing short hairs.

LEGUMINOSÆ—Pea Family.

Melilotus officinalis—Yellow Sweet Clover. (44)
2 mm. Oval with distinct radicle at edge running three-quarters the length of cotyledons, radicle tip slightly out-turned. Surface smooth but distinctly dull, dirty ochreous or greenish-yellow. Vanilla-like smell and characteristic taste of coumarin.

M. alba—White Sweet Clover.
2 mm. Similar in shape, smell, and taste to 44, but surface slightly rough or scabrid.

Trifolium glomeratum—Clustered Clover.

1–1·5 mm. Oval or heart-shaped, pale yellow, similar general appearance to *T. repens*, but the testa is distinctly dull and under the lens minutely warted.

T. procumbens—Prostrate Clover.

1·5 mm. Oval, smooth in outline, very faint indication of radicle position, very highly polished, straw or sulphur or honey or butterscotch-yellow or olive or brown with purplish tinge. Closely similar to *T. minus*. Withered flowers each enclosing one seed often present.

Vicia spp.—Vetches.

In general appearance resembling small peas, often flattened or compressed to a squarish form, some lenticular. Colours light grey, greenish-grey or brownish-grey, often mottled with darker-coloured blotches, hilum distinct and in most elongated. Several species are met with fairly frequently, but generally not in serious amount.

V. angustifolia. (45)

1·2 mm. Mottled, hilum rather short (1 mm.).

V. cracca. (46)

3 mm. Mottled, hilum longer (3 mm.).

V. hirsuta.

2·5 mm. Mottled, slight polish, hilum about one-third of circumference.

V. sepium. (47)

3–4 mm. Usually spotted, hilum very long (8 mm.).

V. tetrasperma.

2 mm. Dark-coloured with very fine spots, hilum about 1 mm.

Lathyrus pratensis—Meadow Vetchling. (48)

3 mm. Globular or oval, smooth with faint gloss, hilum in oval specimens about 1·5 mm., colour variable from greenish-yellow to brown or olive, often blotched with darker colours.

Arthrolobium scorpioides. (49)

4 mm. Flattened sausage-shape, usually slightly curved, longitudinal ridge down flat side, small hilum in middle of outcurved edge, smooth, dull, reddish-brown.

ROSACEÆ—Rose Family.

Poterium sanguisorba et muricatum—Burnets. (50)

4·5 mm. Fruit. Spindle-shaped outline, quadrangular in section, blunt irregular wings down the four edges with a network of irregular deep pits and ridges on surface between wings. Light papery-brown colour. More than one true seed may be contained.

Rosa pratincola—Prairie Rose. (51)
5 mm. Pointed oval, woody texture, pale woody-brown colour, smooth with slight polish.

Potentilla monspeliensis. (52)
1·5 mm. Oval or fat comma- or unbalanced kidney-shape, fan of irregular low ridges on testa, pale-straw or old-hay colour.

ONAGRACEÆ—Willow Herb Family.

Œnothera biennis—Evening Primrose. (53)
1·5 mm. Very variable irregular polyhedral shapes with sharp edges, surface granular and dull, varying shades of reddish-brown.

LYTHRACEÆ—Loosestrife Family.

Lythrum hyssopifolium—Hyssop-leaved Loosestrife. (54)
Usually in the form of pods or broken pieces of pods, cylindrical, narrow (1 mm.), with longitudinal suture, containing one or more small (0·7 mm.), oval, flattened seeds, smooth, pale-brown.

UMBELLIFERÆ—Carrot Family.

Numerous representatives of this very large natural order occur in small amounts. The nature of umbelliferous fruits has been discussed earlier (p. 84). In the following notes upon a selection of species, the descriptions refer to ripe half-fruits, as they occur in threshed samples.

Apium graveolens—Wild Celery.
1·5 mm. See description of celery seed, p. 85.

Conium maculatum—Hemlock. (55)
3 mm. Oval with 5 *wavy* wings on ridges. Dirty-yellow colour, wings lighter. Poisonous.

Æthusa Cynapium—Fools' Parsley. (56)
4 mm. Broadly-oval with small abrupt sharp point, 5 very strong ribs, pale papery-straw colour, two curved orange or reddish stripes on inner (flat) side.

Daucus carota—Wild Carrot.
See description of carrot, p. 84. The spines are usually rubbed off in commercial samples.

Caucalis spp.—Rough Chervils.
2·5 mm. Pear-shape with longitudinal furrow on inner side, surface very rough or prickly with short stiff hairs or bristles, colour dirty-grey, may be merely warty if bristles are rubbed off.

Bupleurum rotundifolium—Hare's Ear. (57)

2·5 mm. Long oval, tapering to truncated snout, may be slightly bent, 10 longitudinal ribs, colour dark brown, brown-purple or nearly black, granular, dull.

RUBIACEÆ—Madder Family.

Galium aparine—Cleavers. (58)

3 mm. Fruit. Nearly spherical with one flattish side where a deep circular pit appears, surface covered with pimples each bearing a strong hooked bristle, colour dirty-grey. (Bristles may be rubbed off.)

G. mollugo and *G. verum* are similar in general form, smaller, and usually rubbed.

Sherardia arvensis—Field Madder. (59)

3 mm. Oval, furrowed longitudinally like a wheat grain, apex carrying a coronet of triangular horn-like lobes, colour dark grey with a covering of short white stiff hairs on body and coronet.

VALERIANACEÆ—Valerian Family.

Valerianella spp. Cornsalad. (69)

2 mm. Oval or flask-shaped, flattened one side, peripheral ridge may be warted, coloured shades of brown.

COMPOSITÆ—Daisy Family.

Most seeds of this order are elongated, usually narrower at base than at apex, often ribbed, often angular in cross-section and bearing a collar, a coronet or a " pappus " (paint brush or sweep's brush) of simple or branched hairs. Compositæ is the largest of the natural orders, and a great variety of its representatives occur as weeds in all parts of the world. The so-called seed is really a fruit.

(*a*) *Ribbed type without hairy pappus.*

Chrysanthemum Leucanthemum—Ox-eye Daisy. (61)

2 mm. Tapered, often with apical knob-like protuberance, dark grey or nearly black body with 10 nearly white ribs, silvery appearance in the mass.

C. segetum—Gilgowan, Corn Marigold. (62)

2 mm. Corn-cob shaped, apex depressed with central conical pimple, 10 rounded ribs, general colour yellow-grey, furrows lighter. Specimens from the periphery of the flower head show a pair of opposite ribs pronounced and edged.

Matricaria inodora—Scentless Mayweed. (63)

2 mm. Square section, tapered, collared, four whitish blunt ribs at angles, side panels dark brown or black, granular of surface.

Anthemis cotula—Stinking Mayweed. (64)

1·5 mm. Short tapered, resembling a wine stopper in form, ribs serrated with rows of warts, blunt conical protuberance at apex, or both base and apex, central axis often slightly curved, dead-straw colour, or dirty-grey.

A. arvensis—Corn Chamomile. (65)

1·5 mm. Similar in outline to 64, with apical pimple, but ribs not warted, hay or straw colour.

Achillea millefolium—Yarrow. (66)

1·5 mm. Flattened, edge ribs often approaching wings, these and other ridges whitish, body chocolate. Yarrow is occasionally used in herbage mixtures.

Cichorium Intybus—Chicory. (67)

3 mm. See description, p. 101.

(*b*) *Ribbed type with pappus*, but *N.B.*, pappus very often missing in threshed seed.

Senecio vulgaris—Groundsel. (68)

2·5 mm. Narrow, often rather shrivelled looking, abruptly tapered towards base, pappus commonly missing and apex flat or cupped, greyish-yellow with darker furrows, hairy with short white hairs.

S. Jacobæa—Ragwort. (69)

1·5 mm. Cylindrical or slightly tapered, axis often slightly curved, smooth with very fine ribs carrying short white hairs, apex usually flat or slightly hollow (pappus missing), colour strawy.

Picris hieracioides—Hawkweed Ox-tongue. (70)

3·5 mm. Shape like a tapered flattened sausage, axis usually curved, longitudinal ribs low, double and serrated, intervening panels transversely ridged, strong dark rich brown, dirty-white pappus of feathered hairs may be present.

P. echioides (*Helminthia*)—Ox-tongue. (80*a*).

3·5 mm. Tapered, sausage form, of polygonal cross-section, transverse ribs becoming prominent at apex, sharp beak, orange-yellow, pappus feathered.

Hypochæris radicata—Catsear. (71)

10 mm. or thereabouts, length varying with proportion of stylar beak remaining, feathery pappus and part of beak usually broken off, spindle-shaped, slender ridges finely serrated, very dark brown.

Sonchus arvensis—Creeping or Corn or Perennial Sowthistle.

3·5–4 mm. Tapered sausage-shape, often flattened, triple serrated ribs, and transverse ridges, apical collar and pimple, rich brown colour.

S. asper—Prickly Sowthistle. (72).

2·5 mm. Flat, snowshoe-shaped, three ribs each side apart from edge ribs, intervening panels smooth, uniform dull pale brown.

S. oleraceus—Common Sowthistle. (73)

As 72, but panels transversely ridged.

Crepis virens—Smooth Crepis. (74)

2 mm. Short sausage-shaped, axis curved, 10 ribs strongly developed, no beak, hay colour, pappus when present white and not feathered.

Lapsana communis—Nipplewort. (75)

4 mm. Narrow club-shaped, axis curved, ribs narrow, often not prominent, smooth somewhat shining surface, pale strawy colour.

(*c*) *Unribbed or ribs obscure, pappus usually gone.* The thistles form a group here.

Cnicus arvensis—Creeping Thistle. (76)

3·5 mm. Slightly tapered short club-shape, smooth, polished, axis bent aside near apex, distinct collar and apical nipple, neutral brown colour.

C. lanceolatus—Spear Plume Thistle. (77)

3·5 mm. Generally similar to 76, but less tapered, whiter, less polished, ruled with fine longitudinal striations, nipple small.

(*d*) *Unribbed or obscurely striated, with pappus.*

Centaurea Cyanus—Cornflower. (78)

3 mm. (without pappus), short thick club-shape, distinctly notched near base, apical collar, crowned by thick brush of stiff bristles giving a " paint-brush " effect, strawy colour at base, bluish- or grey-tinged white above, with fine white longitudinal ribs.

C. nigra—Knapweed. (79)

3·5 mm. Generally similar to 78, but with less prominent crown of fewer and shorter bristles.

(*e*) *Irregular form.*

Ambrosia artemisiæfolia—American Ragweed. (80)

3 mm. General shape conical or urn-like, stout apical snout and narrow base, coronet of upward projections below snout, variable longitudinal ribs and surface veins, dull, greenish-grey or grey-brown, contents oily (crush).

Many other composites will be met with. They can usually be referred to their order, or even genus, by family resemblance.

CAMPANULACEÆ—Canterbury Bell Family.

Seeds of *Campanula* spp. or *Specularia* spp. may occasionally be met. They are usually tiny (*c.* ½ mm.) treacle- or toffee-brown and very highly polished.

PRIMULACEÆ—Primrose Family.

Anagallis arvensis—Scarlet Pimpernel. (81)
1 mm. Irregular shape, commonly tetragonal with slightly curved faces, roughly granular, dark brown or reddish-sepia colour.

CONVOLVULACEÆ—Bindweed Family.

Cuscuta Trifolii et spp.—Large- and Small-seeded Dodder. (82)
2 mm. *or* 1 mm. Irregularly-globular or squat pear-shape, often with two somewhat flattened faces, slightly rough surface (like cheese-rind), colour ochreous or grey-yellow, or dirty dark-grey, with a circular or elliptical lighter patch. Easily mistaken for a fragment of soil (crush). Parasitic on legumes and some other crops.

C. Epilinum—Flax Dodder. (83)
1·5 mm. Similar to 82, usually of the ochreous type and commonly met with in united pairs.

Convolvulus arvensis—Lesser Bindweed. (84)
4·5 mm. Pot-bellied flask-shape, flattened on two sides which meet in a straight bull-nosed ridge, dull warty surface, sooty black.

BORAGINACEÆ—Forget-me-not Family.

Myosotis arvensis et spp.—Forget-me-not. (85)
1–1·5 mm. Ovate or tear-drop shape, pointed one end, somewhat flattened, recurved rim, jet black when ripe and highly polished.

Lithospermum arvense—Gromwell. (86)
2·5 mm. Pear-shape with two flattened smooth faces and an outer warty curved surface, upper end flat, colour neutral grey (dry soil colour), with whitish end surface.

Echium vulgare—Viper's Bugloss. (87)
3·5 mm. Generally similar to 86, but with more rugged appearance, sharper angles and rougher warts, dark brown.

OROBANCHACEÆ—Broom-rape Family.

Orobanche minor—Lesser Broom-rape.
Microscopically small seeds (0·25 mm.), sooty black, kidney-shaped and reticulately-pitted like poppy seeds.

SCROPHULARINEÆ—Foxglove Family.

Linaria spuria—Round-leaved Toadflax. (88)
1 mm. Oval, surface thrown into very characteristic strong ridges and pits suggesting a rubber sponge, colour dark brown.

L. Elantine—Pointed Toadflax.
Similar to 88, but half as large again.

Veronica spp.—Speedwells.
0·5–3 mm. Oval, globular or pear-shaped, corrugated, a depression on one side varying from a shallow hollow to a deep wide pit in different species, colour yellow, texture waxy.

Euphrasia officinalis—Eyebright. (89)
1·5 mm. Oblong or spindle-shaped, general resemblance to timothy but flattened and often twisted, clear narrow longitudinal white ribs, dark brown between. Partially parasitic on grass roots.

Bartsia odontites—Red Bartsia. (90)
1·5 mm. Very similar to *Euphrasia*, but uniform whitish colour and with fine transverse striations between the longitudinal ribs. Partially parasitic on grass.

Rhinanthus Crista-galli—Yellow Rattle. (91)
4·5 mm. Kidney-shaped outline, flat, broadly winged, thickened central disc olive or brown, wing papery and yellowish or dirty-white. Partial parasite on grass.

LABIATÆ.

"Seeds" are quadrant portions of fruit, and have two flat sides meeting at a right angle and one rounded surface.

Salvia spp.—Sages. (92)
Oval or very broadly pear-shaped, dull, curved outer surface veined or warty or granular, browns and greys.

Nepeta Cataria—Catmint. (93)
1·5 mm. Oval outline, dull, finely granular under lens, dark grey or nearly black, a pair of white moustache-shaped scars near base.

Prunella vulgaris—Self-heal. (94)
1·75 mm. Oval, tapering to white basal point, smooth, general colour a bright old-hay brown. Scored with pairs of slightly curved darker lines down centre of rounded side and edges.

Galeopsis tetrahit et ladamun—Hemp Nettles. (95)
3 mm. Pear-shaped, mottled greys and browns, surface scurfy, oily (crush).

Teucrium spp.—Woodsages. (96)
1–2 mm. Ovate, more or less pointed, netted or pitted on rounded surfaces, brown shades.

VERBENACEÆ—Vervain Family.

Verbena spp.—Vervains. (97, 97*a*)
2 mm. Oblong, ends rounded, one side flattened or keeled and creamy colour flecked with white, outer rounded side brown, smooth, with sharp longitudinal branching ribs.

PLANTAGINEÆ—Plantain family.

(*a*) *Dug-out canoe-shaped types.*

Plantago lanceolata—Ribgrass. (98)
2·5 mm. From suggestive of a date stone, " gunwale " edges on hollow side rounded, scar in centre of hollow, colour treacle-brown with lighter strip down centre of round side, texture horny, gummy if wet.

P. aristata—Bracted Plantain. (99)
More clean cut, " gunwale " edges square, scar a pair of pits, equatorial round-bottomed groove across round side, colour smoky purple-brown.

(*b*) *Irregular polyhedral type.*

P. major—Broad Plantain. (100)
1 mm. Wedge, spindle or irregular outline, raised towards centre one side, slightly rounded other side, scar on raised side with very fine ridges radiating from it visible under lens, colour dull brown, horny.

P. rugelii—Rugel's Plantain. (101)
2 mm. Similar in form to 100 but darker colour (nearly black), and, while rough, not definitely netted with ridges.

AMARANTHACEÆ—Love-lies-bleeding Family.

Amaranthus retroflexus—Pigweed. (102)
1 mm. Outline nearly circular but with radicle tip projecting slightly in a shallow notch, biconvex, edge thin and " turned up" forming a shallow channel round the seed, colour jet black when ripe, highly polished.

CHENOPODIACEÆ—Beetroot Family.

Chenopodium album—Fat hen. (103)
1·5 mm. Circular, flattened, edges rounded (shape of a

Dutch cheese) with radicle tip projecting slightly. Colour black if ripe, shining if naked. Often partially enclosed in white papery 5-partite husk.

Atriplex spp.—Oraches. (104)
2·5 mm. Naked seeds similar to 103 but larger, more granular surfaced, less uniform black and often found (on edge) within the dry flower, consisting of two three-toothed leaves applied face to face.

Salsola kali—Russian Thistle. (105)
1·5 mm. Yellowish or dirty-grey if naked. Shape suggestive of a pudding in a basin, apical beak. Often enclosed in a conical, ragged, papery husk.

POLYGONACEÆ—Dock Family.

Seeds of this order described are all glossy, some highly so, if naked, but part or all of the floral envelope is often present investing the seed, papery, light, or red-brown, wrinkled.

(*a*) *Triangular-section, pointed spindle types.*

Rumex obtusifolius—Broad Dock. (106)
2 mm. One end a little more tapered than the other, colour chestnut to dark brown, polished.

R. crispus—Curled Dock. (107)
1·5–2 mm. As 106, but difference in taper of two ends a shade more marked, more flask-shaped, and commonly smaller.

R. Acetosa—Common Sorrel. (108)
1·5–2 mm. Similar to 106 but taper equal at two ends, no "flask neck," darker richer colour, often whitish towards one end.

R. Acetosella—Sheep's Sorrel. (109)
1 mm. Very broad short spindle form, equally tapered at ends, light to dark brown, polished if naked but presence of husk very common.

Polygonum Convolvulus—Black Bindweed. (110)
3·5 mm. Nearly equal taper at ends, edges of spindle well rounded, colour black, smooth; fragments of adherent grey or brown husk at base common; pearly if skinned.

P. aviculare—Knotgrass. (111)
2·5 mm. Distinctly more taper at apex than at base, blunt point, finely granular surface, reddish-brown colour, basal snout giving a "bellows" outline, fragments of husk commonly adhering at base.

(*b*) *Flattened flask-shaped type.*

P. Persicaria—Redshank. (112)
2 mm. Fat tear-drop outline, one side slightly bowed, the other with large rounded median longitudinal ridge, black, shining; fragments of grey or whitish adherent husk common, may have short pointed basal snout.

P. hydropiper—Water Pepper. (112*a*)
1·5–2 mm. Narrower form than 112, grey or brown.

URTICACEÆ—Nettle Family.

Urtica dioica—Stinging Nettle. (113)
1 mm. Broadly oval, slightly more tapered at apex than base, short point both ends, greenish-yellow colour if naked, finely granular surface; fragments of withered flower often present.

EUPHORBIACEÆ—Spurge Family.

Euphorbia spp.—Spurges. (114, 114*a*)
1–2 mm. Shaped like very fat orange sections, somewhat thicker at upper end than lower, warty granular or pitted surface, colour yellowish, bluish, brown, or grey.

JUNCACEÆ—Rush Family.

Juncus spp.—Rushes. (115)
Less than 0·5 mm. Tiny spindle-shaped seeds of orange-yellow colour, translucent in texture. Will not germinate till April of year following harvest.

CYPERACEÆ—Sedge Family.

Scirpus spp., *Carex* spp.—Sedges. (116)
2–5 mm. Fruits flask-shaped, rounded or triangular in section, often snouted at base and drawn out into a neck at apex, may be hairy, colours dirty-grey, greenish, or brown.

GRAMINEÆ—Grass Family.

See general characters of grass "seeds" described in earlier crop-seed section (p. 86).

Panicum sanguinale—Crab Grass. (117)
3 mm. Whole spikelet with one seed. Canoe-shaped, five longitudinal ribs on flatter side, small scale adherent at base of rounded side, short woolly hairs, general colour grey-green, no awn. (*P. crus-galli* is awned.)

Setaria viridis—Green Foxtail. (118)
2·5 mm. Broad boat-shape, flowering glumes hard and very closely investing the kernel, five veins on outer, inner shows very fine transverse lines under lens, colour greenish-yellow.

S. glauca—Yellow Foxtail. (119)
2·5 mm. Similar to 118, but transverse ridging coarser and colour usually darker. Outer side often has small basal scale.

Alopecurus agrestis—Black Foxtail.
See p. 92.

A. geniculatus—Knee'd Foxtail.
See p. 92.

Aira flexuosa—Waxy Hairgrass. (120)
3·5 mm. Spindle-shaped, basal tuft of silky hair, basal awn longer than flowering glumes, papery dark brown glumes (cf. golden oatgrass which has a dorsal awn and lighter colour).

A. caryophyllea—Silvery Hairgrass. (121)
1·5 mm. Similar in structure to 120, but much smaller, nearly black and with awn not quite basal.

Holcus lanatus—Yorkshire Fog. (122)
4 mm. Spikelet. Flattened, outer (empty) glumes strongly keeled, thin, papery, nearly white or with violet tinge, surface finely pimpled under lens, keels with forward-pointing short hairs, hooked awn scarcely projecting beyond notched mouth of glumes. If " shelled " out of empty glumes, silvery grey, lopsided flask-shape, 2 mm., shining, no hair, oily (crush).

H. mollis—Creeping Soft Grass. (123)
As 122, but more pronounced and less hooked awn.

Agropyrum repens—Couch Grass. (124)
10 mm. Resembles ryegrass, with short stiff awn, outer flowering glume 7-nerved, flat usually slightly hairy rachilla, hay colour, usually no kernel. Several unseparated florets often occur in a piece.

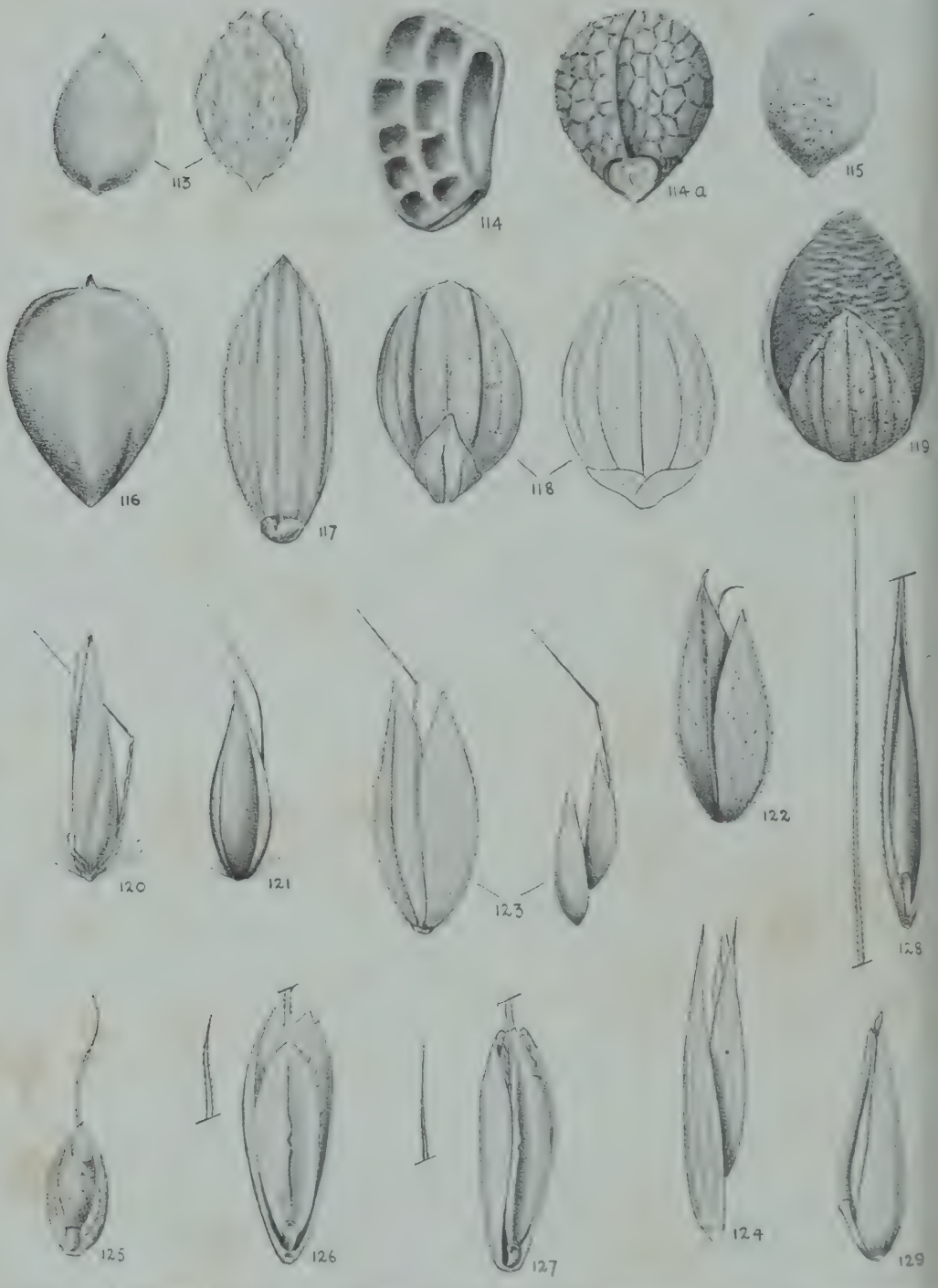
Lolium temulentum—Darnel. (125)
6 mm. Swollen boat-shape, rather suggestive of a small barley grain, short stiff awn, smooth flat wedge-shaped rachilla. Poisonous.

Bromus mollis—Soft Brome. (126)
8 mm. Inflated boat-shape, broader towards top, outer flowering glume 3-nerved, apex notched and often toothed, short stiff awn arising at notch, inner flowering glume semi-transparent and fringed on edges, kernel chocolate or purple-brown, rachilla round and bent backward.

FIGS. 54–75.—54—Lythrum hyssopifolium. 55—Conium maculatum. 56—Æthusa Cynapium. 57—Bupleurum rotundifolium. 58—Galium aparine. 59—Sherardia arvensis. 60—Valerianella dentata. 61—Chrysanthemum Leucanthemum. 62—C. segetum. 63—Matricaria inodora. 64—Anthemis cotula. 65—A. arvensis. 66—Achillea millefolium. 67—Cichorium Intybus. 68—Senecio vulgaris. 69—S. Jacobæa. 70—Picris hieracioides. 71—Hypochæris radicata. 72—Sonchus asper. 73—S. oleraceus. 74—Crepis virens. 75—Lapsana communis.

FIGS. 76 96.—76—Cnicus arvensis. 77—C. lanceolatus. 78—Centaurea Cyanus. 79—C. nigra. 80—Ambrosia artemisiœfolia. 80*a*—Helminthia echioides. 81—Anagallis arvensis. 82—Cuscuta Trifolii. 83—C. Epilinum. 84—Convolvulus arvensis. 85.—Myosotis arvensis. 86—Lithospermum arvense. 87—Echium vulgare. 88—Linaria spuria. 89 Euphrasia officinalis. 90—Bartsia odontites. 91—Rhinanthus Crista-galli. 92—Salvia officinalis. 93—Nepeta Cataria. 94—Prunella vulgaris. 95—Galeopsis Tetrahit. 96—Teucrium Botrys.

FIGS. 97–112*a*.—97—Verbena officinalis. 97*a*—V. urticæfolia. 98—Plantago lanceolata. 99—P. aristata. 100—P. major. 101—P. Rugelii. 102—Amaranthus retroflexus. 103—Chenopodium album. 104—Atriplex patula. 105—Salsola Kali. 106—Rumex obtusifolius. 107—R. crispus. 108—R. Acetosa. 109—R. Acetosella. 110—Polygonum Convolvulus. 111—P. aviculare. 112—P. Persicaria. 112*a*—P. Hydropiper.



FIGS. 113–129.—113—Urtica dioica. 114—Euphorbia peplus. 114*a*—E. helioscopia. 115—Juncus bufonius. 116—Scirpus maritima. 117—Panicum sanguinale. 118—Setaria viridis. 119—S. glauca. 120—Aira flexuosa. 121—A. caryophyllea. 122—Holcus lanatus. 123—Holcus mollis. 124—Agropyrum repens. 125—Lolium temulentum. 126—Bromus mollis. 127—B. secalinus. 128—Festuca sciuroides. 129—Molinia cærulea.

B. arvensis is similar to 126.

B. secalinus—Rye-like Brome. (127)

Similar to 126 but more turgid, the kernel filling the husk more completely, and the edges of the outer flowering glume more inrolled.

Festuca sciuroides—Rat's-tail Fescue. (128)

Body of seed 6 mm., awn longer than body, elongated " racing canoe " shape, round backed, " open " in front, outer flowering glume only clasping edge of inner towards base, rachilla round and bent backward, tapering slightly to base, colour dark purplish-tinged brown.

Molinia cærulea—Purple Moor Grass. (129)

4 mm. Elongated flask-shape, apex keeled and often curved, smooth outer flowering glume 2-nerved, pointed but without any awn, long hairy rachilla knobbed at apex, colour grey-brown or with violet tinge.

Chapter Five

The Seeds Act, 1920: An Account of its Provisions and Administration

A. W. MONRO, C.B.

(Late Principal in charge of the Commercial and Seeds Branch, Ministry of Agriculture and Fisheries)

Historical. It is only of comparatively recent date that legislation has been enacted with the object of regulating and controlling the sale of agricultural and garden seeds in this country.

The first measure of this nature was the Adulteration of Seeds Act, 1869 (amended by the subsequent Act of 1878), which made it an offence to sell within the United Kingdom any killed or dyed seeds, and which thereby dealt with the practice of adulterating parcels of useful seeds by the addition of dead seeds of other species, the presence of which would not be apparent after sowing as they would not germinate. About the same time other countries began to take measures, of either a voluntary or compulsory nature, to control the trade in seeds, so that before the outbreak of the First Great War regulations were in force in most continental countries, the United States of America, and several of the British Dominions, with the object of preventing the sale of seeds of low vitality and seeds containing a dangerous proportion of injurious weed seeds.

As far as this country is concerned, while no further legislation was enacted between 1878 and the early years of the present century, various private seed-testing stations were established in the interests of the trade. In 1900, a Departmental Com-

mittee set up by the then Board of Agriculture to inquire into the conditions under which agricultural seeds were being sold in this country, recommended that a seed-testing station should be set up for the assistance of farmers, but that the trade should not be further controlled by legislation. In the same year the first *official* seed-testing station in the United Kingdom was established in Ireland and a few years later the Weeds and Agricultural Seeds Act, 1909, applicable to Ireland only, was passed giving the Irish Department of Agriculture a certain measure of control over the sale of seeds. Early in 1914, the Board of Agriculture for Scotland established an official seed-testing station, but no legislative control of seeds accompanied it.

Although the establishment of an English official station had been discussed from time to time over a period of years, it was not until the urgent needs of food production during the war made it imperative to stimulate the production of crops, that steps were taken to control the seed supply and to establish an official testing station. The tendency of official control during the earlier days of the war was in the direction of assuring and increasing output, regulating and fixing prices, and requiring disclosure of quality of the supplies sold. In 1917, however, the first Testing of Seeds Order was made under the Defence of the Realm Regulations and an official testing station was set up in London [1] for the purposes of the Order. The Order actually became operative in January, 1918, and it was replaced in July, 1918, by the Testing of Seeds Order, 1918, which remained in operation until August 1, 1921, when the Seeds Act, 1920, came into force.

The main provisions of the Seeds Act, 1920, apply with necessary modifications equally to Scotland as to England and Wales, but, as far as Ireland is concerned, the Act is not operative in the Irish Free State and only certain provisions relating to the presence of injurious weed seeds are effective in Northern Ireland, except in respect of cross-channel sales, i.e. sales from Northern Ireland to a purchaser in Great Britain or vice versa, when the regulations made under the Act are held to apply.

For convenience of administration it was decided not to

[1] Now situated at Cambridge (see pp. 134, 135).

include in the Act complete details of the control to be exercised under it. These details are incorporated in Regulations made under the provisions of the Act and are capable of amendment as may be necessary to deal with new conditions as they may arise. The Regulations at present in operation are the Seeds Regulations, 1922, which came into force on August 10, 1922.

The Seeds Act, 1920, may be said to be largely an agreed measure. Before its introduction the various trade interests were consulted and a common measure of agreement formed the basis of the Act, which has proved itself to be a valuable minor reform in the interests of agriculture. Little wonder then that its requirements have been accepted in good part by the general body of seedsmen as well as farmers, and that such suggestions as have been made in recent years with regard to the revision of the Act or the amendment of the Regulations have not been concerned with main principles, but solely with such details as changing conditions inevitably bring up for review.

The Seeds Act, 1920.[1] The preamble to the Act states that its object is " to amend the Law with respect to the sale and use of seeds for sowing and . . . to provide for the testing thereof." The Act is, in fact, applicable to all the principal kinds of cereal, grass, clover, root, and vegetable seeds, details of which are specified in the Seeds Regulations, 1922.

The fundamental principle of the Act is embodied in its first Section, which requires that a declaration of the percentage of germination and purity, the presence of injurious weeds, and other specified particulars, shall be made in writing to the purchaser at or before the time of sale or delivery of the seed.

It will be seen, therefore, that the object of the Act is not to compel the farmer to use seed of a better quality than that which he is prepared to buy, nor to prohibit the sale of seeds below specified minima of purity and germination, but to

[1] It is convenient to confine this section to the Act and Regulations relating to the sale of seeds as distinct from seed potatoes, which are dealt with separately later (see p. 131 et seq.).

require the seller to disclose certain essential facts that will enable the purchaser to judge the comparative quality of the seed he obtains. Apart from a restriction applying to certain prescribed injurious weed seeds, a person may sell seeds of any quality, provided that he declares what the quality is.

It may be noted in particular, also, that the Section applies to "every person who sells," i.e. *it affects the sale of seeds from farmer to farmer as well as from seedsman to farmer.*

In addition to the delivery of particulars on sale by the seller to the purchaser, the display of a statement of particulars, on or in close proximity to the seeds, is required whenever they are *exposed* for sale.

As far as concerns the actual delivery of a statement to a purchaser, use is made of the ordinary business methods, i.e. the statement must be contained in a sale note or invoice or it must be attached to, inserted in, or written on, the package containing the seeds. Where seeds firms issue printed price lists or catalogues that contain the prescribed particulars of the seeds listed therein, they may, if they so desire, make specific reference to such price list or catalogue in their written statement given on sale. In such circumstances the statement is accepted as equivalent to the declaration of the required particulars.

In order to ensure that particulars of purity, germination, etc., shall be reliable, the Act further requires that no seed scheduled under the Act may be offered for sale in this country unless tested either (1) at one of the official seed-testing stations, or (2) at some testing station licensed by the Minister, or (3) as regards garden seeds, "in any other sufficient manner." It should be explained that there are three *official* seed-testing stations in existence in the United Kingdom, viz. one at Cambridge (originally in London), one at Belfast, and one at Edinburgh. In addition there are in England and Wales some eighty testing stations licensed by the Minister, all of which are the property of, or are connected with, individual firms engaged in the seed trade. (Further reference is made to the seed-testing stations on pp. 135, 137.)

It is, of course, also necessary to safeguard the purchaser against the possibility of seed being sold to him on the strength

of a declaration based on an old test, and it is therefore required that in relation to all sales made during the months of October to July inclusive the test used for the purpose of the statutory declaration must have been made not earlier than the preceding August. For sales made in August or September the test shall not have been made before August of the previous year.

As regards injurious weed seeds, to which reference has already been made, the Act not only prohibits the sale or exposure for sale, but also the *sowing* of any of the scheduled seeds that contain more than a certain percentage of the seeds of the prescribed injurious weeds.[1]

The Act provides for the enforcement of its requirement by enabling the Minister to give duly authorized persons power to enter any premises where seeds to which the Act applies are sold or exposed for sale or stored for purposes of sale, and to take samples. Such samples may be taken without payment and the owner must on demand deliver to the authorized person taking the samples a statement containing such particulars as he would be required to give to a purchaser. The manner of taking statutory samples of seeds is prescribed by the Seeds Regulations, and the " control " samples are divided into two parts, each of which is marked, fastened up, and sealed. One part is then tendered to the owner and the other part is dispatched to the official seed-testing station. On the result of the test at the station a certificate is completed, a copy of which is sent to the owner. Any such certificate issued by the station is held, for the purpose of proceedings against the owner of the seed, to be conclusive evidence of the facts stated in the certificate, unless within fourteen days of its receipt by him the owner applies for a further portion of the sample to be tested both at that station and at some other official testing station. When further portions are tested in this manner it is laid down that if the results of the tests at the two official stations differ, the average of the figures shall be deemed to be the result of the tests for the purposes of the Act.

[1] The Seeds Regulations, 1922, contain the actual details, but it will render further reference unnecessary if it is here stated that the injurious weed seeds specified are docks and sorrels, cranesbills, wild carrot, Yorkshire fog, and soft brome grass; the maximum percentage permitted is 5 per cent. by weight.

If there is any material discrepancy between the statement delivered by the owner of the seed and the result of the official test, and if the owner had purchased the seed from some other person, the former is required to furnish, on demand by the Minister, the name and address of the person from whom he purchased the seed, together with a copy of the statement delivered to him by the earlier seller. On being approached by the Minister concerning the discrepancy the said seller has the same right as the owner to require a second test.

Having prescribed the foregoing general requirements and procedure, the Act includes reference to certain limitations of its scope. It is declared that the Act does not apply to the sale of seeds under the following conditions:

(*a*) When sold to a person " purposing to purchase them with a view to cleaning them before they are sold or exposed for sale."

(*b*) When the purchaser at the time of the sale gives the seller " an undertaking in writing that he will before selling or exposing the seeds for sale test or cause them to be tested, or that he will not resell the seeds to a seed merchant except on a similar undertaking by the purchaser." (This exemption is made to cover a sale of seeds through a " string " of merchants. It enables such seed to be passed from merchant to merchant without the necessity of a statement containing the prescribed particulars being delivered in each instance.)

(*c*) When sold for delivery outside the United Kingdom; and

(*d*) When sold for some purpose other than for planting or sowing.

Moreover, the Act empowers the Minister, under certain conditions, to grant a licence of exemption from the statutory requirements in respect of the declaration of particulars. The circumstances under which such an exemption may be granted are indicated in the Seeds Regulations, 1922, and further reference is made thereto on p. 130.

Legal proceedings in respect of offences under the Seeds Act can only be instituted by the Minister, and each case is heard at a court of summary jurisdiction. In general, it may be said that if any person

(*a*) fails to comply with or acts in contravention of any provision of the Act,

(*b*) makes or causes to be made any statement required under the Act which is false in a material particular, or

(*c*) obstructs or impedes in the exercise of his duties any person authorized to enter any premises for the purpose of the Act,

he is liable on summary conviction to a fine not exceeding £5, in the case of the first offence, and £10 in the case of a second or subsequent offence. As regards (*b*) there is a safeguarding clause which exempts from conviction any person who is able to prove that the particulars alleged to be false were ascertained on a test of the seeds made in accordance with the provisions of the Act, or, as regards purity or germination percentages, that the actual percentages do not differ from the stated percentages by more than certain prescribed limits of variation. These limits are set out in detail in the Fifth Schedule of the Seeds Regulations, 1922.

The heaviest penalties are reserved for any person who tampers with any sample taken under the Act or who tampers with any seeds so as to prevent the taking of a properly representative sample, or who, with intent to deceive, is responsible for any sample being sent for testing which to his knowledge does not correctly represent the bulk of the seeds. For these offences there is the penalty, on summary conviction, of a fine not exceeding £20 or imprisonment for a term not exceeding six months.

One section only of the Act bears on the question of civil claims arising out of contracts for the sale of seeds to which the Act applies. This section safeguards the seller, in the event of legal proceedings, by laying it down that the particulars contained in a statement delivered to the purchaser in pursuance of the Act shall be deemed to be true unless the contrary is shown as a result of a further test undertaken at the request of the purchaser within ten days of the date of delivery of the seeds.

The remaining sections of the Act are mainly concerned with details of interpretation, financial provisions, and the modifications necessary in the application of the Act to Scotland and Ireland.

The Seeds Regulations, 1922.[1] The Seeds Regulations, 1922, specify in detail the kinds of seeds to which the provisions of the main Act apply. The seeds are as follows:

(*a*) Grass and clover seeds of the following kinds (under whatever trade names sold) except where sold or exposed for sale for a purpose other than an agricultural purpose:

Perennial Ryegrass	Alsike Clover
Italian Ryegrass	White Clover
Meadow Fescue	Crimson Clover
Cocksfoot	Trefoil
Crested Dogstail	Lucerne
Timothy	Sainfoin
Red Clover	

(*b*) Cereal seeds of the following kinds:

Wheat	Oats
Barley	Rye

(*c*) Field seeds of the following kinds:

Tares or Vetches	Field Cabbage	Field Peas
Field Turnip	Field Kale	Field Beans
Swede	Field Kohl Rabi	Sugar Beet
Rape	Mangold	

(*d*) Garden seeds of the following kinds:

Peas	Brussels Sprouts
Dwarf and Broad Beans	Broccoli
Runner Beans	Cauliflower
Garden Turnip	Carrot
Garden Cabbage	Parsnip
Garden Kale	Beet
Garden Kohl Rabi	Onion
Garden Swede	

(*e*) Flax seed and linseed.

(*f*) Forest tree seeds of the following kinds:

Coniferous.

Scots Pine, *Pinus silvestris*, L.
Austrian Pine, *Pinus austriaca*, Hoess.
Corsican Pine, *Pinus Laricio*, Poir.
European Larch, *Larix europæa*, D.C.
Japanese Larch, *Larix leptolepis* Endl.

[1] The Seeds Regulations, 1922, are operative in England and Wales only, but similar regulations were also made by the Department of Agriculture for Scotland and the Ministry of Agriculture, Northern Ireland, as regards Scotland and Northern Ireland respectively.

Douglas Fir (Oregon or green Douglas), *Pseudotsuga Douglasii*, Carr.
Douglas Fir (Colorado or blue Douglas), *Pseudotsuga Douglasii*, var. *glauca*, Hort.
Norway Spruce, *Picea excelsa*, L.
Menzies or Sitka Spruce, *Picea Menziesii*, Carr.
Silver Fir, *Abies pectinata*, D.C.
Silver Fir (grand), *Abies grandis*, Lindl.
Hemlock Spruce, *Tsuga Mertensiana*, Carr.
Red or Canoe Cedar, *Thuya gigantea*, Nutt. (syn. *plicata*, Don. or syn. *Lobbii*, Hort.).

Broadleaved.

Common Oak (Sessile), *Quercus sessiliflora*, Salisb.
Common Oak (Pedunculate), *Quercus pedunculata*, Ehrh.
Beech, *Fagus sylvatica*, L.
Ash, *Fraxinus excelsior*, L.

The particulars that must be stated in the event of sale or exposure for sale vary to some extent according to the kind of seed, but there are, broadly speaking, five essential items, viz:—

(1) the name and address of the seller,
(2) a statement that the seeds have been tested in accordance with the provisions of the Act,
(3) the kind of seed,
(4) the percentage of purity (except for cereals), and
(5) the percentage of germination.

Certain additional particulars are required with some seeds; for instance, with cereals, red clover, white clover, crimson clover, and sainfoin, the distinctive name of the variety must be stated, or if the variety is not known, or the stock is mixed, a statement is required to that effect. The country of origin—a most important detail—has to be declared in respect of grass and clover seeds, flax seed and linseed, and forest tree seeds. Also, with grass and clover seeds, the total percentage weight of the specified injurious weed seeds (if over 1 per cent for clovers and 2 per cent for grasses) must be stated, as well as the presence of dodder in certain circumstances. As far as items (4) and (5) of the above are concerned it was appreciated when the regulations were framed that it would be inconvenient, and would indeed cause unwarrantable interference with trading operations, if a declaration of the exact percentages of purity and

Kind of Seed	Name and Address of Seller	That the Seeds have been tested in accordance with the Seeds Act, 1920	Country of Origin	Kind of Seed	Distinctive Name of Variety	Purity per cent by Weight	Impurities			Number per cent of Hard Seeds	Total Germination per cent by Number	Authorized Minimum percentage of Germination (*a*)
							Total per cent by Weight of Injurious Weeds if over 1 per cent	Whether Dodder is present				
								If more than 1 Seed in 2 oz.	If more than 1 Seed in 4 oz.			
Grass and Clover Seeds												
Perennial ryegrass (*b*)	×	×	×	×	—	× (*f*)	× (*c*)	—	—	—	× (*g*)	85
Italian ryegrass (*b*)	×	×	×	×	—	× (*f*)	× (*c*)	—	—	—	× (*g*)	80
Mixture of perennial and Italian ryegrasses (*b*)	×	×	×	×	—	× (*f*)	× (*c*)	—	—	—	× (*g*)	82
Cocksfoot	×	×	×	×	—	×	× (*c*)	—	—	—	×	—
Meadow fescue	×	×	×	×	—	×	× (*c*)	—	—	—	×	—
Timothy	×	×	×	×	—	×	× (*c*)	×	—	—	×	—
Crested dogstail	×	×	×	×	—	×	× (*c*)	—	—	—	×	—
Red clover	×	×	×	×	×	×	×	—	×	×	×	—
Alsike clover (*k*)	×	×	×	×	—	× (*h*)	×	×	—	×	×	—
White clover (*k*)	×	×	×	×	×	× (*h*)	×	×	—	×	×	—
Wild white clover	×	×	×	×	×	× (*h*)	×	× (*d*)	—	×	×	—
Crimson clover	×	×	×	×	×	×	×	—	×	×	×	—
Trefoil	×	×	×	×	—	×	×	—	—	×	×	—
Lucerne	×	×	×	×	—	×	×	—	×	×	×	—
Sainfoin	×	×	×	×	×	× (*e*)	×	—	—	×	×	—
Cereal Seeds												
Wheat	×	×	—	×	×	—	—	—	—	—	× (*g*)	90
Barley	×	×	—	×	×	—	—	—	—	—	× (*g*)	90
Oats	×	×	—	×	×	—	—	—	—	—	× (*g*)	85
Rye	×	×	—	×	×	—	—	—	—	—	× (*g*)	80
Field Seeds												
Tares or vetches	×	×	—	×	—	× (*f*)	—	—	—	—	× (*g*)	90
Mangold	×	×	—	×	—	× (*f*)	—	—	—	—	× (*g*)	60 (of clusters)

Swede	×	×	—	×	—	× (f)	—	—	—	—	× (g)	80
Rape	×	×	—	×	—	× (f)	—	—	—	—	× (g)	80
Turnip (field)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	80
Cabbage (field)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Kale (field)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Kohl rabi (field)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Peas	×	×	—	×	—	× (f)	—	—	—	—	× (g)	80
Beans (field)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	90
Sugar beet	×	×	—	×	—	× (f)	—	—	—	—	× (g)	60 (of clusters)
Garden Seeds												
Pea	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Dwarf and broad beans	×	×	—	×	—	× (f)	—	—	—	—	× (g)	75
Runner beans	×	×	—	×	—	× (f)	—	—	—	—	× (g)	60
Parsnip	×	×	—	×	—	× (f)	—	—	—	—	× (g)	45
Onion	×	×	—	×	—	× (f)	—	—	—	—	× (g)	60
Carrot	×	×	—	×	—	× (f)	—	—	—	—	× (g)	50
Beet	×	×	—	×	—	× (f)	—	—	—	—	× (g)	50 (of clusters)
Turnip (garden)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	75
Cabbage (garden)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Kale (garden)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Kohl rabi (garden)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Swede (garden)	×	×	—	×	—	× (f)	—	—	—	—	× (g)	75
Cauliflower	×	×	—	×	—	× (f)	—	—	—	—	× (g)	60
Brussels sprouts	×	×	—	×	—	× (f)	—	—	—	—	× (g)	70
Broccoli	×	×	—	×	—	× (f)	—	—	—	—	× (g)	60
Other Seeds												
Flax seed and linseed	×	×	×	×	—	×	—	—	×	—	×	—
Forest tree seeds	×	×	×	×	—	×	—	—	—	—	×	—

(*a*) Seeds with a germination of less than the authorized minimum percentages may be sold provided the actual percentage of germination is declared.
(*b*) The imperial bushel weight of the ryegrasses must also be declared.
(*c*) The total percentage by weight of injurious weed seeds in grasses must be declared when over 2 per cent.
(*d*) Dodder must be declared if present in excess of one seed in 1 oz. of wild white clover.
(*e*) Where burnet is present in sainfoin to an extent of more than 5 per cent by weight, the exact percentage present must be declared.
(*f*) If the percentage of purity of the ryegrasses is not less than 98 per cent, a statement to that effect is sufficient, and the purity of field and garden seed need not be stated unless it is below 97 per cent (or 90 per cent in the case of carrot seed).
(*g*) If the germination is not less than the authorized minimum percentage of germination prescribed in the Seeds Regulations, 1922, a statement to that effect, which shall include the authorized minimum percentage, is sufficient.
(*h*) If the percentage of suckling clover (*Trifolium dubium* Sibth.), hop clover *procumbens* (*T.* L.), *T. parviflorum* Ehrh., *T. angulatum* Wladst., and *T. glomeratum* L. exceeds 2 per cent by weight the exact percentage must be declared.
(*k*) Where alsike and white clovers are grown together and are so described, particulars may be stated for the mixture as a whole.

germination were required in every instance. By reference, therefore, to certain specified purity percentages and to what are termed the " authorized minimum percentages of germination," set out in the first four Schedules to the Regulations, it is permissible, where so indicated in the Regulations, to make a general declaration to satisfy the Act's requirements.

As, however, confusion may well result from any attempt to deal comprehensively with the various provisions contained in the Regulations, the tabular statement and notes on pp. 127–128 are given, setting out the details in convenient form. The mark (×) opposite any kind of seed indicates that the particulars set out in the heading have to be declared on sale of the seed in Great Britain.

In addition to the foregoing, special provisions have been made to meet the needs of the packet trade. As regards packets of peas and beans (not exceeding 2 lb.) or of any other garden seeds (not exceeding 8 oz.) the requirements indicated above do not apply if the following particulars are stated on the packet:—

> (1) name and address of seller; (2) that the seeds have been tested in accordance with the Seeds Act, 1920; (3) kind of seed; (4) percentage of purity if below 97 per cent (90 per cent in the case of carrot); (5) percentage of germination, provided that if such is at or above the minimum percentage specified in the Regulations a statment to that effect is sufficient; and (6) the season in which the seeds were packeted.

Sampling. In view of the importance attaching to the results of tests of seed it is clearly essential that, as far as possible, every sample taken for testing should be truly respresentative of the bulk from which it is drawn. To this end the Regulations contain specific instructions concerning the manner in which samples must be taken. Similarly, requirements are laid down as to the minimum weight or quantities of samples, according to the kind of seed, as it is essential that sufficient seeds shall be included to enable the testing station to make an adequate and reliable test. It is not necessary to give full details here, but a memorandum dealing with sampling and the size of samples may be obtained, free of charge, on application to the Secretary, Ministry of Agriculture and Fisheries, 10 Whitehall Place, London, S.W.1. (See, however, p. 57 et seq., and p. 137.)

Licence of Exemption. Reference has been made on p. 123 to the licence of exemption, and in the Regulations it is laid down that such a licence may be granted in any instance in which the Minister is satisfied that the circumstances are such that compliance with the requirements as regards declaration of particulars on sale or exposure for the sale cannot reasonably be enforced.

Two uses of this provision call for mention:—

(1) In order to avoid delay in the delivery of new seed corn urgently required for sowing, a general licence has been issued by virtue of which the particulars to be declared in respect of seed wheat, barley, oats, or rye may be delivered to the purchaser within one month of the sale instead of at or before the time of sale or delivery, as is normally required. This concession applies only to cereal seeds sold up to April 30 of the year following that in which they were harvested.

(3) The Forestry Commission occasionally imports from abroad consignments of forest tree seeds for sale in this country. Again with the object of avoiding delay in sowing while the necessary test is being undertaken at the Official Seed-Testing Station, the Minister has, on application received from the Forestry Commission, customarily issued a licence in accordance with the regulations exempting the Commission from compliance with the requirement to deliver particulars on or before sale or delivery.

It will be appreciated that exemption licences are rarely issued and then only to meet exceptional circumstances.

Definitions, etc. The Regulations further include definitions of certain terms, viz. purity, impurities, percentage of purity, percentage of germination, as used for the purposes of the Act. It is also laid down that when a sample of one of the scheduled grass and clover seeds contains more than 15 per cent by weight of other seeds (not being weed seeds) the sample shall be deemed to be a mixture.

Finally, the Schedules to the Regulations, besides including the authorized minimum percentages of germination and the limits of variation, to which reference has already been made, include the form of certificate that the Official Seed-Testing Station for England and Wales must use for the purpose of

reporting the result of a test of a sample drawn by a duly authorized person.

The Seeds Act and Regulations in Respect of Seed Potatoes. The main principles of the Seed Act, 1920, relate equally to the sale of seeds and seed potatoes. The requirements to deliver particulars on sale; the necessity for declaring particulars on exposure for sale; the power of entry for the purpose of taking samples; the non-application of the Act to sales for delivery outside the United Kingdom or for use other than for sowing or planting; the power of granting exemption; the penalties for infringement of the Act—these all cover transactions in seed potatoes.

There are certain provisions in respect of sales of seeds that do not apply to seed potatoes—principally those relating to tests—and, on the other hand, special legislation has been passed to deal with seed potatoes only.

Experience of the operation of the Seeds Act, 1920, revealed the fact that misstatements as to the variety of seed potatoes frequently did not come to light until more than six months after the sale of the seed. As legal proceedings under the Act have to be instituted within six months of the date of the offence it was considered desirable, by means of an amending Act, to extend to twelve months the period for taking proceedings in respect of a false statement as to class or variety of seed potatoes. The Seeds (Amendment) Act, 1925, was therefore passed to deal solely with this particular point.

As regards the Seeds Regulations, 1922, these were subsequently amended by the Seeds (Amendment) Regulations, 1935, which revised the former classification for seed potatoes and introduced additional classes in respect of high-grade seed potatoes produced in England and Wales. Apart from the alteration of classification, however, there has been no variation of the main requirements contained in the Seeds Regulations, 1922, which prescribe that the following particulars[1] must be declared on sale or exposure for sale of seed potatoes:—

[1] In addition to these particulars, sellers are also required to state the number of the official certificate under the Wart Disease of Potatoes Order of 1923.

(1) the name and address of the seller,
(2) the class of the seed,
(3) the variety, and
(4) the " size and dressing."

Instead of the original four classes, however, there are now six classes as follows:—

Class 1 (Scotch)—potatoes grown in Scotland.

Class 1 (Irish) potatoes grown in Ireland.

Class 1 (English Special Stock) } potatoes grown in England and Wales respectively " under the provisions of a
Class 1 (Welsh Special Stock) } of a scheme authorized by the Minister."

Class 1 (English once-grown)—potatoes grown in England and Wales which are (*a*) the produce of seed grown in Scotland or Ireland in the preceding year, or (*b*) the produce of seed included in the Special Stock classes in the preceding year, such produce not being grown in accordance with a scheme authorized by the Minister.

Class 2—all other potatoes.

As regards variety, this is not held to be incorrectly stated if at least 97 per cent of the total quantity sold or exposed for sale is true to the variety declared. If the potatoes are of mixed varieties a statement to that effect is sufficient.

" Size and dressing " is defined as meaning the size of the mesh (exclusive of the thickness of the wire) of the riddles through and by which, respectively, the potatoes may be passed and retained. If potatoes are sold " as grown," and with that written description, it is unnecessary to make reference to the size of the mesh of the top riddle.

General Administration and Enforcement. The Ministry of Agriculture and Fisheries is charged with the administration and enforcement of the Seeds Act in England and Wales. For this work the Ministry has a small headquarters' staff

and is also able to call upon the services a number of Inspectors in all parts of the country.

During the first few years of the Act's operation a considerable amount of attention was naturally given to educational work among both seedsmen and farmers. Particularly was the Ministry concerned to impress upon growers the importance of good seed and the value of the safeguards and facilities available under the Act. By means of lectures by inspectors and agricultural education staffs throughout the country, by press notices and articles in agricultural journals, by seed exhibits at agricultural shows, and meetings in scores of towns and villages, efforts were made to give publicity to the new measure. The need for such educational activities has become less essential as the provisions of the Act have become more widely understood and as conformity with the requirements has become a normal part of the procedure of the seed trade. At the same time a certain amount of educational work will always be necessary for the benefit of those coming new into the trade and of the " casual " seller whose periodical incursions into the seed business do not facilitate a comprehensive knowledge of the various requirements.

The chief means of oversight of the trade in seeds, however, has been and will continue to be the visits paid by Inspectors to seedsmen, merchants, retailers, farmers, etc., all over the country, and the drawing of control samples for check testing at the Official Seed-Testing Station.

For administrative purposes the country is divided into a number of areas, each area being allocated to a particular Inspector who in addition to other duties has responsibility for the seeds work in his area. In addition there is a senior General Inspector who, with the assistance of a special Seeds Inspector, is responsible for the general oversight of the whole country. The usual procedure is for a yearly quota of visits and control samples to be allotted to each Inspector for his particular area. This is fixed having regard to the nature, extent, and peculiar requirements of each area, and represents what is considered to be necessary to secure reasonably adequate contact with the trade. From the records of their visits, etc., and their practical experience, Inspectors are able to form a

very good idea of the general measure of compliance with the provisions of the Act and of any particular direction in which special attention is needed.

The Inspectors are not expected to take control samples from each seedsman visited. Their primary object is to ascertain whether the requirements of the Act are being carried out. Their advice may also be necessary on points of doubt. They are nevertheless empowered to inspect any stocks of seeds, whether on sale or stored for sale, and to draw control samples if they consider this to be desirable. A figure of about 1,400 to 1,500 control samples annually represents the normal extent of this sampling, and during recent years the number of samples calling for special attention has amounted to some 6 to 8 per cent of the total. A number of these, however, relate to incomplete or irregular declarations, and the percentage of instances in which there has been any discrepancy in respect of purity or germination, outside the specified limits of variation, is considerably lower.

While, naturally, the bulk of the Inspectors' visits are made to seedsmen, merchants, and retailers, many visits are also made to farmers, particularly where the latter are understood to be regular dealers in seeds, as well as growers. It is obviously difficult to keep check of farmer to farmer sales, but the trend of affairs in recent years has tended to lessen the number of those sales in which, all too frequently, the safeguards of the Seeds Act have been ignored. In the course of their visits to farmers Inspectors seek opportunity, when convenient, to draw informal samples of seeds as delivered for sowing. These samples supply the Ministry with valuable information concerning the quality of seed supplied to those who sow it and the delivery of the statutory particulars in respect of actual business transactions.

The testing of control samples in England and Wales is undertaken by the Official Seed-Testing Station, Cambridge. The Official Station is a state-aided establishment and its reputation and prestige stand high both in this country and abroad. The testing of control samples taken by Inspectors is, indeed, only a comparatively small part of the work done by the Station, which is being increasingly used by traders for

the testing of seeds of all kinds and for the purpose of declaration on sale. Under the Seeds Act, however, as has already been indicated, the Minister is empowered to license *private* testing stations. At the time of the passing of the Act it was considered that this privilege should be granted to certain well-known firms who had old-established and well-equipped seed-testing plant and analysts trained for the work. Some of these private seed-testing stations are licensed for the testing of all kinds of seeds to which the Act applies, while others are licensed to test only certain specified kinds of seed. The conditions under which licences are granted to private stations do not permit them to test samples of seeds for the information of farmers or others on payment of a fee. The conditions set out in the licence make it clear that such a station is to be maintained and used solely for the testing of seeds required by the licensee for his own purchases and sales.

The oversight of these private licensed stations, with the object of maintaining a high standard of efficiency, is again the Ministry's responsibility. The stations are visited periodically, and what are called " Reserved Portions "—duplicate samples of seeds tested by the stations—are drawn and dispatched to the Official Station for check testing. The comparison of results assists the Ministry to form its conclusions as to the efficiency of the individual stations. It may be said that, on the whole, the work of the private licensed stations is done in an efficient manner, and, when difficulties present themselves, advice and assistance are freely given by the Official Seed-Testing Station and by the Ministry's Inspectors.

It will be seen that the Ministry's policy of administration and enforcement includes educational, advisory, and inspectorial activities. During the first few years of the operation of the Act, it was the policy of the Ministry invariably to pass over a " first offence " before instituting legal proceedings for a breach of the requirements of the Act. Since then, each case has been considered on its merits, and although it will still be more usual to try the effect of a warning before more drastic action is decided upon, it may happen, in special circumstances, that legal proceedings will be taken for a first offence. At the same time it is the general rule not to prosecute

before giving the alleged offender an opportunity to submit any explanation he may have to offer.

The Ministry's experience of the Seeds Act in operation indicates that the measure, in its main essentials, can definitely be regarded as a permanent part of this country's agricultural legislation. In a trade where there is so much scope for honest misjudgment as well as dishonest deception regarding the quality of the article sold, it seems essential, if confidence in the trade is to be maintained, to retain legislation of this nature, which, while laying down permanent and fundamental principles, also permits of adjustment in detail as circumstances may require.

NOTE.—The foregoing account (pp. 118–136) gives a fairly complete account of the procedure of seed control in England and Wales. Attention is particularly directed to the paragraph on p. 119 referring to the position in Scotland and Northern Ireland in relation to the Seeds Act, 1920. Persons in those countries who desire to have seeds officially tested should apply respectively to the Department of Agriculture for Scotland, Edinburgh, or the Ministry of Agriculture for Northern Ireland, Belfast.

Appendix One

Crop Seeds: Physical Data

Physical Data

Average Samples

Species	Greatest Dimension *	Weight per 1,000	Bushel Weight	Number per lb.
	Millimetres	Grammes	lb.	
Barley	11.0	46	56	9,800
Bean (field)	11.5	550	65	700
,, Soya	7.7	150	50	3,000
Beet	5.0	12	19	37,500
Bent	2.0	0.1	37	4,500,000
Bird's-foot Trefoil	2.0	1.2	66	400,000
Cabbage, vars.	2.4	3.0	55	110,000
Carrot	2.8	1.0	30	300,000
Celery	1.4	0.3	—	1,500,000
Clover, Alsike	1.3	0.7	66	700,000
,, Crimson	2.8	3.5	65	120,000
,, Red	2.2	2.0	65	230,000
,, Suckling	1.5	0.5	66	1,000,000
,, White Dutch	1.2	0.7	66	730,000
,, White Wild	1.0	0.5	65	900,000
Cocksfoot	5.0	1.0	22	450,000
Dogstail	4.0	0.5	36	900,000
Fescue, Hard	5.0	0.8	23	570,000
,, Meadow	7.0	1.9	30	200,000
,, Red	6.5	1.1	16	346,200
,, Sheep's	5.0	0.8	28	1,500,000

* Omitting awn where present.

Physical Data—*continued*

Average Samples

Species	Greatest Dimension *	Weight per 1,000	Bushel Weight	Number per lb.
	Millimetres	Grammes	lb.	
Fescue, Tall	9.0	1.9	24	240,000
Fiorin	2.0	0.1	37	4,500,000
Flax	6.0	4.5	54	105,000
Foxtail	7.0	1.0	12	480,000
Kidney Vetch	2.5	2.2	64	150,000
Leek	3.2	3.0	—	150,000
Lucerne	2.8	2.0	64	220,000
Mangold	5.5	20.0	22	24,000
Meadow gr., Rough-st.	2.7	0.2	30	2,000,000
,, ,, Smooth-st.	2.5	0.2	32	1,800,000
Mustard, Black	1.3	1.8	55	200,000
,, White	2.3	5.5	50	80,000
Oatgrass, Golden	4.5	0.3	12	1,000,000
,, Tall	8.0	3.2	14	140,000
Oats, Common	12.0	40.0	42	12,000
Onion	3.5	3.8	—	118,400
Parsnip	7.0	4.0	18	110,000
Pea, Field	9.4	230.0	64	1,700
Poa, Rough-st.	2.7	0.2	30	2,000,000
,, Smooth-st.	2.5	0.2	32	1,800,000
Rape	2.2	4.2	52	110,000
Rye	8.4	27.8	54	20,000
Ryegrass, Italian	7.0	1.8	22	250,000
,, Perennial	7.0	2.0	28	225,000
Sainfoin (milled)	4.5	16.0	70	40,000
,, (unmilled)	—	22.0	28	25,000
Swede	2.2	3.0	56	128,600
Timothy	1.7	0.3	50	1,200,000
Trefoil	2.2	1.6	66	300,000
Turnip	2.0	2.5	50	150,000
Vetch	5.0	60.0	64	8,500
Wheat	6.7	50.0	63	10,000

* Omitting awn where present.

Appendix Two

Notes and Data for Practical Seed Testing

The amounts, periods, methods, etc., shown in the table on pp. 142–144 are convenient, and in all ordinary cases sufficient for routine tests upon the species mentioned. Explanations of the contractions and symbols used are given below.

EXPLANATION OF TABLE

Purity Analysis. The quantities shown are for individual separations; replicate tests should *each* be made upon such quantities. Where two figures are given the *second* of the two is required to comply with the rules of the International Seed-Testing Association.

The contractions used are as follows:—

Germinators

C. = *Cabinet* One of the several available types of thermostatic closed incubators. For most general purposes a glazed door is desirable. Petri dish, flannel, or sand tests may be conducted in such an incubator.

Ch. = *Chamber.* A small room with provision for heating and temperature control. Electric heat is preferable to gas, since it gives no appreciable combustion products. Control of heat is very satisfactorily attained by means of a thermostat and cut-out of the Grundy type. Temperature records may conveniently be kept in such a chamber by means of a clockwork thermograph. A germination chamber is only required where large numbers of samples requiring sand-pot tests are undertaken. A cabinet may always be used alternatively.

J. = *Jacobsen.* Since these are constantly half-full of warm water and must be kept perfectly clean, it is very desirable to have them made of a " stainless " metal such as Monel, If of copper, care must be taken to avoid scouring off the tin plating and exposing the copper. Temperature control is facilitated if the glass strips upon which the papers rest are arranged to close the mouth of the tank as completely as possible. The papers are individually covered by small ventilated bell-jars made for the purpose. This has proved more satisfactory than enclosing the whole tank with a lid. Light should be good, but diffused; direct sunlight and draughts should be avoided.

P. = *Petri dishes.* There are commonly used in a cabinet and may be of aluminium. The latter are preferable for most purposes. Petri dishes used with filter-paper are best covered with a flat glass plate pierced for ventilation. Four-inch dishes are a convenient size for 100 small seeds on filter-paper.

R. = *Rodewald.* The sand for Rodewald germinators should be fine and must be burnt and well washed before use. It should be reburnt each time a germinator is refilled. In watering, the sand should be kept just saturated, but only just—the dishes, pressed firmly upon (not into) the surface should " suck " when lifted.

P.W. = *Petri with wick.* See f.p.w.

Seed Beds

f.p. = *Filter-paper.* Good quality white filter-paper is required. For Petri-dish tests circular papers to fit the bottom of the dish are used in pairs; for Jacobsen tests, a pair of rather stiffer papers, such as Whatman's No. 3 of 9 cm. diameter, each pair moistened by a " wick " cut from an embossed thin filter-paper strip an inch wide, dipping into the water of the tank and lying at its upper end on the glass plate supporting the seed papers; for flannel tests, a good white blotting paper is satisfactory.

f.p.w. = *Filter-paper with wick.* A Petri dish is half-filled with water and covered with a pierced plate. A single strand of cotton wick is coiled on the plate and passed through the piercing into the water. A pair of filter-papers is then laid on top, and the whole covered with a bell jar. This forms a miniature germinator on the Jacobsen principle and is useful for tests in which a plentiful supply of moisture is needed.

Species	Purity Analysis	Germinator	Seed Bed	Temperature †	Germination Period *	
					Energy	Capacity
	Grammes			° C.	Days	Days
Barley	50	C. or Ch.	s.	19–22 x	5	10–7
Bean, Broad	200	C. or Ch.	s.	19–22	5	10
,, Runner	100	C. or Ch.	s.	19–22	5	10–7
Beet	25	C. or Ch.	s.	22~30	7	14
Bent	0.25–0.5	J.	f.p.	18~25	10	28–16
		P.W.	f.p.w.	Sun ‡	10	28–16
Cabbage, vars.	4–3	R.	p.	22	5	10
		P.	f.p.	22	5	10
Carrot	2–1	C.	s.	22~30	10	21–16
		C.	f.p.	22~30	10	21–16
Celery	1	C.	s.	22~30	10	21
			f.p.	22~30	10	21
Clover, Red	4	R.	p.	22	4–5	10
		C.	fl.	22		
,, Alsike	2	R.	p.	22	4–5	10
,, White		C.	fl.	22	4–5	10
Cocksfoot	1	C.	f.p.	22~30	10	21–18
		J.	f.p.	18~25	10	21–18
Dogstail	1	R.	p.	22	10	28–21
		J.	f.p.	18~25	10	28–21
Fescue, Meadow	2–3	R.	p.	22	7	14
		J.	f.p.	18~25	7	14

„ Small spp.	1	R.	p.	22	10	21
		J.	f.p.	18~25	10	21
Flax	4–5	R.	p.	22	3–5	10–7
Foxtail	0.1–1	R.	p.	22	10	28–21
		C.	f.p.	22~30	10	28–21
Kidney Vetch	4	R.	p.	22	4–5	10
		C.	fl.	22	4–5	10
Leek	4–5	R.	p.	22	7	14–12
		C.	f.p.	19	7	14–12
Lucerne	4	R.	p.	22	4–5	10
		C.	fl.	22	4–5	10
Mangold	25	C. or Ch.	s.	22~30	7	14
Meadow Grasses	0.5	J.	f.p.	18~25	10	28
		P.W.	f.p.w.	Sun ‡	10	28
Mustard	4–3	R.	p.	22	4–5	10
		C.	f.p.	22	4–5	10
Oatgrass	3	R.	p.	22	7	14
		J.	f.p.	18~25	7	14
Oats	50	C. or Ch.	s.	19	5	10
Onion	4–5	R.	p.	22 xx	7	14–12
		C.	f.p.	19	7	14–12
Parsnip	3	R.	p.	22	10	28
		C.	f.p. or s.	22~30	10	28
Pea	100	C. or Ch.	s.§	19–22	5	10–8
Rape	4–3	R.	p.	22	4–5	10
		C.	f.p.	22	4–5	10
Rye	50	C. or Ch.	s.	19–22 x	5	10–7

Species	Purity Analysis	Germinator	Seed Bed	Temperature †	Germination Period *	
					Energy	Capacity
	Grammes			°C.	Days	Days
Ryegrass	2–3	J.	f.p.	18~25	7	14
Spinach	4	R.	p.	19	7	14–21
		C.	f.p.	12	7	14–21
Timothy	2–1	R.	p.	22	5	10–12
		J.	f.p.	18~25	5	10
Trefoil	4	R.	p.	22	4–5	10
		C.	fl	22	4–5	10
Turnip	4–3	R.	p.	22	5	10
		C.	f.p.	22	5	10
Vetch	50	C. or Ch.	s.	19–22	5	10
Wheat	50	C. or Ch.	s.	19–22 x	5	10–7

fl. = *Flannel.* A moderately thick good quality white flannel, thoroughly washed and shrunk, is wrung out in water, folded double, and laid on a clean tray. Blotting paper rectangles are folded across the middle and laid on the flannel, the seeds being held within the fold of the paper, A cabinet incubator is used and water added as necessary from a spray.

p. = Unglazed porcelain dishes specially made for use in Rodewald germinators.

s. = *Sand.* A fairly fine sharp sand, thoroughly washed and burnt, and moistened to about 60 per cent of its capacity, so that it will just cohere when squeezed in the hand. The surface is made smooth and seeds are pressed into the sand but not covered (except peas—see §).

* = *Germination periods.* Where two figures are given the *second* is required by the rules of the International Seed-Testing Association.

† = *Temperature.* The expression x—y means that a constant temperature within the range $x°$ C. to $y°$ C. is suitable; $z \sim y$ means alternation of temperature, 18 hours at $x°$ C. and 6 hours at $y°$ C.

‡ = *Sunshine tests.* These are placed on window sill or staging in a warm room or warmed greenhouse. Filter-paper with wick is generally used.

§ = *Sand tests.* With peas the seeds are placed in holes in the sand, of depth about twice the diameter of the pea, and are then covered with a sprinkling of *dry* sand as a precaution against spread of mould.

x = Treatment for delayed germination (wheat, barley, and rye)—3 days drying at 40° C. before planting.

xx = Treatment for delayed germination (oats)—germinate at lower temperature, preferably starting at 5° C. for two days.

Index

Absolute humidity, 24
Absolute weight, 61
Achillea millefolium, 109
Acotyledons, 5
Æthusa Cynapium, 107
After-ripening, 9, 10, 16, 18, 69
Agropyrum repens, 82, 116
Agrostis, 45, 51, 52, 61, 69, 73, **93**, **94**, 96
Agrostis alba, 94
Agrostis canina, 94
Agrostis palustris, 94
Agrostis repens, 94
Agrostis stolonifera, **45**, 94
Agrostis tenuis, 45, **94**
Aids, artificial, to germination, 72
Aira caryophyllea, 116
Aira flexuosa, 116
Albuminous seeds, 7, 55
Aleurone grains, 79
Allium cepa, 86
Allium porrum, 86
Alopecurus agrestis, 82, **92**, 116
Alopecurus geniculatus, **92**, 116
Alopecurus pratensis, 59, **91**
Alsike, 14, 16, 66, **95**, 96, 98
Alsike seed supplies, 40, 44
Amaranthaceæ, 113
Ambrosia artemisiæfolia, 51, 110
America, shipment to, 24
America (U.S.), prohibited species, 50
American Ragweed, 51, 110
Ammi majus, 51
Anagallis arvensis, 111
Analysis (purity), 59
Analysts, earliest, 46
Analysts' reports, 73
Analytical sample, **58**, 61
Annual Meadow Grass, 92
Anthemis arvensis, 109
Anthemis cotula, 109
Anthoxanthum, 91, 96
Anthyllis vulneraria, 99
Antipodes, shipment to, 24
Apium graveolens, **85**, 107
Apparatus, germination, 70
Apples, storage of, 23
Arrhenatherum avenaceum, 72, **91**
Arthrolobium scorpioides, 106
Ascochyta pisi, 64
Aspergillus, 65
Association, European Seed-Testing, 48
Association, International Seed-Testing, 15, **48**, 54
Atriplex, 82, 114
Atriplex patula, 82
Australia, shipment to, 27
Avena fatua, 82
Avena flavescens, 91
Avena orientalis, 80
Avena sativa, 80
Avena strigosa, 82
Ayrshire, Ryegrass seed from, 37
Ayrshire, Timothy seed from, 37

Bacillus radicicola, 41
Bacteria, 41, 69
Balances, 61
Ball Mustard, 103
Bamboo, 86
Barbarea vulgaris, 103
Barley, 63, 65, **79**
Barley, malting, 80
Barley, varieties, 79, 80
Bartsia odontites, 112
Bartsia Red, 112
Beans, 7, 14, 58, **99**
Beans, Soya, 100
Beans, species and varieties, 99
Becquerel, 11, **13**
Beet, 17, 64, **85**
Beet seed production, 42
Beet, Sugar, 85
Beetroot family, 113
Bell-jars (Jacobsen), 70
Bent, 45, 52, 69, **93**
Bent species, **93**, 94
Beta vulgaris, 85
Bindweed, Black, 82, 85, 114
Bindweed family, 111
Bindweed, Lesser, 82, 85, 111
Bird's-foot Trefoil, 100
Black Foxtail, 82, 92, 116
Black Grass, 92
Black Mustard, 84, 103
Black Winter Oats, 9, **18**
Blight, seedling, 65
Blocks, Rodewald, 70
Bluegrass, Canada, 92
Bluegrass, Kentucky, 50, 92, 93
Boraginaceæ, 111
Brandspores (Bunt), 63
Brassica nigra, 84, 103
Brassica sinapis (arvensis), 82, 103
Brassica, species and varieties, **83**, 84
Bread Wheat, **79**
Brenchley, Winifred, 11
British Association Committee, 11
Broken seeds, 33, 41, **54**
Brome, rye-like, 117
Brome, soft, 49, 52, **116**
Bromus, **49**, 50
Bromus arvensis, 117
Bromus mollis, 116
Bromus secalinus, 117
Broomrape family, 112
Broomrape, Lesser, 112

Browntop, 45, **94**
Bruchus, 57
Bugloss, Vipers', 111
Bulks, sampling of, 57, **58**
Bunt, 32, **63**
Bupleurum rotundifolium, 108
Burnet, 50, **106**
Burnt corn, 57
Bushel weight, 27, **61**, 73
Buttercup, Celery-leaved, 69, 102
Buttercup, Creeping, 102
Buttercup family, 102
Buttercup, Field, 102
Buttercup, Upright, 139.

Cabbage, 83
Cabbage family, 103
Cabbage, seed supply, 41
Cabbage, species and varieties, 83
Cabinet incubator, 70
Calcicole Legumes, 98
Cambridgeshire, Ryegrass seed from, 37
Camelina microcarpa, 103
Camelina sativa, 103
Campanulaceæ, 111
Campion(s), 96
Campion(s), Bladder, 104
Campion(s), Red, 104
Campion(s), White, 67, 104
Canada, Alsike seed from, 44, 66
Canada Bluegrass, 92
Canada, prohibited species, 50, 85
Canada, Timothy seed from, 45, 89
Canada, White Clover seed from, 44
Cane, Sugar, 86
Canterbury Bell family, 111
Capsella Bursa-pastoris, 104
Caraway, 85
Carbonization, 10
Carex spp., 115
Carnation family, 104
Carrot, 18, 23, 56, 69, **84**
Carrot family, 107
Carrot, Wild, 49, 67, **107**
Caryophyllaceæ, 104
Catmint, 112
Catsear, 109
Caucalis species, 107
Celery, 64, 85
Celery-leaved Buttercup, 69, 102
Celery, rust disease of, 64
Celery, Wild, 107
Cell division, 2, 3
Cell, female and male, 2
Cell, reproductive, 2
Cell, zygote, **3**
Centaurea Cyanus, 110
Centaurea nigra, 110
Central Europe, White Clover seed from, 44
Centrifugal machine, **29**, 30
Cerastium triviale, 105
Cereal samples, condition in, 81
Cereal samples, heating in, 81
Cereal supply, home-grown, 36
Cereals, 7, 10, 18, 35, 61, 63, 67, **78**, 86
Cereals, ergot, 63
Cereals from Egyptian tombs, 10
Cereals, ripening in, 21
Cereals, varieties, 36
Cereals, weeds of, 82
Certificate, International Association's, 48
Certification of bulks, 46
Certification of crops, 40, 43
Chamomile, Corn, 109
Characters, diagnostic, 66, 67, 96
Charlock, 13, 82, 83, 103
Chemicals to assist germination, 72
Chenopodiaceæ, **85**, 113
Chenopodium album, 12, 113
Chervils, rough, 107
Chevalier Barley, 80
Chickweed, 51, 96, **105**
Chickweed, Mouse-eared, 96, 105
Chickweed, seed weight, 52
Chicory, 101, 109
Chili, Red Clover seed from, 44
Chilean Red Clover, 66, 67
" Chilean Ryegrass," 91
Chives, 86
Chloral hydrate colour test, 83, **103**
Chloris ciliata, 10
Chondrometer, 62
Chromosome number, 3
Chromosomes, 2
Chrysanthemum Leucanthemum, 108
Chrysanthemum segetum, 108
Cichorium Intybus, 101, 109
Claviceps species, 51, **63**
Cleaning of seed, **27**, 34
Cleanings, disposal of, **34**, 35
Cleavers, 82, 108
Clover, 7, 9, 11, 14, 15, 17, 21, 32, 60, 64, **94**
Clover, Alsike, 14, 16, 40, 52, 66, **95**, 96
Clover, Alsike, production of seed, **40**, 44
Clover, Broad Red, 38, **94**
Clover, Broad Red, fertilization of, 38
Clover, Clustered, 106, 128
Clover, Crimson, 14, **97**
Clover, Crimson, seed supply, 41
Clover, cyanogenesis in, 97
Clover, Dutch White, 14, 39, **96**
Clover, Dutch White, seed production, 39
Clover family, 14
Clover, indigenous strains, 39, **43**
Clover, Late Flowering Red, seed production, 38, **94**
Clover, parasitic eelworm in, 38
Clover, producing districts, 38, 39, 40, 41

Clover, Prostrate, 106, 128
Clover, Red, 11, 14, 15, 29, 32, 36, 38, 51, 64, 66, 67, 75, 76, **94**
Clover, Red, Chilean, 51, 66, 67
Clover, Red, English, 66, 67
Clover, Red, French, 67
Clover, Red, harvesting of, 39
Clover, Red, Italian, 66, 67
Clover, Red, New Zealand, 36, 44
Clover, Red, New Zealand Wild White, 44
Clover, Red, North American, 36, 51
Clover, Red, seed production, 38
Clover, Red, Single-cut, 38
Clover, Red, South American, 66
Clover, Red, South European, 66
Clover, Red, Swedish, 36
Clover, Red, varieties, 36
Clover, Red, wild strains, 95
Clover, ripening in, 21
Clover, seed supplies, **36**, 38, 39, 40, 41, 44
Clover, sickness in, 38, 40, 64
Clover, Strawberry, 98
Clover, Subterranean, 98
Clover, Suckling, 50, **97**, 128
Clover, Sweet, 50, 105
Clover, White, 14, 16, 20, 38, 39, 40, 44, 51, **96**
Clover, White S.100, 40
Clover, Wild White, 14, 38, 39, 51, **96**
Clover, Wild White, certification scheme, 40, 43
Clover, Wild White, diagnosis of, 96
Clover, Wild White, harvesting of, **39**, 40
Clover, Wild White, indigenous strains, 43
Clover, Wild White, old pasture, 51
Clover, Wild White, once grown, 51
Clover, Yellow Sweet, 105
Cnicus arvensis, 110
Cnicus lanceolatus, 110
Cockles, Ear-, 57
Cocksfoot, 17, 18, 23, 43, 52, 53, 55, 58, 60, 64, 69, **88**
Cocksfoot, Aberystwyth, 43
Cocksfoot, indigenous strains, **43**
Cocksfoot, New Zealand, 89
Cocksfoot, seed supply, home grown, 38
Cold storage, 19
Coleoptile, 79
Colletotrichum lini 65
Colour test, chloral hydrate, 83, **103**
Combination of weed seeds, 67, 82, 96
Commercial seed production, 20
Common Oats, 80
Common Poppy, 102
Common Sorrel, 49, 114
Common Sowthistle, 110
Common Turnips, 83
Compositæ, 101, 108
Condition in cereal samples, 81
Conditions for germination, 68
Conditions, uniformity of, in storage, 23
Conium maculatum, 107
Contamination, bacterial, 68
Contamination, fungoid, 68
Contarinia, 57
Continental method, 54
Control sample, 72, 122
Conventions, International Association's, **47**, 48
Convolvulaceæ, 111
Convolvulus arvensis, 82, 85, 111
Corn, " burnt," 57
Corn Chamomile, 109
Corn Cockle, 104
Corn, Indian, 81
Corn-salad, 108
Cornflower, 110
Cosh, 22
Cotswolds, 40, 41
Cotyledon, **7**, 55, 65, 67
Couchgrass, 82, 116
County Antrim, Crested Dogstail seed from, 37
County Down, Crested Dogstail seed from, 37
County Down, Wild White Clover seed from, 40
Cow Cockle, 104
Cow, digestive tract, 12
Crabgrass, 115
Cracked seed, 41, 54
Cranesbill, Cut-leaved, 67, 105
Cranesbill, Small-flowered, 105
Cranesbill, Soft, 34, 51, 67, 96, 97, 105
Creeping Soft Grass, 116
Creeping Thistle, 110
Crepis, Smooth, 110
Crepis virens, 110
Cress, 84
Cress, Field, 103
Cress, Penny, 104
Cress, Winter, 103
Crested Dogstail, 37, 51, **90**, 96
Crocker, 11
Crop certification, 43
Crops, fibre, 43
Crops, leguminous, 94
Crops, miscellaneous, 100
Crops, pulse, 99
Crops, root, 83
Crops, vegetable, 83
Cross-fertilization, 2
Cruciferæ, **83**, 84, 103
Cruciferous seed, 41
Cursor, 62
Cuscuta, 31
Cuscuta Epilinum, 111
Cuscuta Trifolii, 111
Cuticle, 14
Cyanogenesis in clover, 97
Cyanophoric test, 97
Cynosurus cristatus, **90**, 96

Cynosurus echinatus, 44, 91
Cyperaceæ, 115

Dactylis glomerata, 88
Daisy family, 101, 108
Daisy, Ox-eye, 50, 108
Damage by insects, 55
Damage by mice, 55
Danish experiments, 75
Darnel, 65, 88, 116
Daucus carota, 49, 67, **84**, 107
Death, 10, 23
Declaration, Seeds Act, 1920, 15
Declarations, Seed Regulations special, 50
Definition of terms in Seeds Regulations, 1922, 130
Delayed germination, **18**, 69, 73
Delphinium consolida, 102
Denmark, seed supply from, 44, 45
Departmental Committee, on seeds, 1909, 118
De-seeding, 22
Desiccation, 8
Destruction of weeds, compulsory, 50
Diagnostic characters, 66, 67, 96
Diaphanoscope, 60
Dicotyledons, **5**, 7, 9
Digestion, 12
Diploid number, 3
Disease, **63**, 73
Disease, Ergot, 63, 64
Disease, fungoid, 63
Disease, Leaf-stripe, 65
Disease, Phoma, 64
Disease, Rust, 64
Disease, Rust of Celery, **64**, 85
Disease, seed-borne, 64
Disease, Seedling Blight, 65
Disease, Smut, **63**
Disease, Spot of Peas, 64
Disposal of Cleanings, 34
Distilled water, 15, 68
Division, cell, 2
Division, reduction, 3
Dock, Broad, 114
Dock, Curled, 67, 82, 114
Dock family, 114
Docks, 13, 49, 50
Dodder, 31, 32, 44, 49, 50, 60, 67, **73**, 89, 111
Dodder, Clover, 111
Dodder, Flax, 111
Dodder machine, 60
Dogstail, Crested, 37, 39, **90**, 96
Dominions, seed supply from, 44, 45
Drøfter truge, **29**, 60
Drying, artificial, 25
Duration of life, 1, 13
Duration of test, 69
Dutch system of winnowing, 60
Dwarf French Beans, 99

Ear-Cockles, 57
Earthnut, 99
East Anglia, 40, **41**, 42
Echium vulgare, 111
Eelworm, 38, **57**
Embryo, 2, 3, 5, 7, 8, 55, 56, 79
Embryo damage, 55
Embryo development, 8
Embryo root, 5
Embryo shoot, 5
Embryogenetic development, 56
Empty husks, 53
Endosperm, 7
Endosperm accumulation, 56
Endosperm nucleus, primary, 7
Endosperm tissue, 7
Energy germination, 69, **73**, 75
England, 23, 38, **39**, 40
English Red Clover, 66, 67
Epigeal behaviour, 7
Epilobium angustifolium, 14
Ergot, 51, **63**, 64, 65, 81
Error, experimental, 72
Error, personal, 70
Eruca sativa, 103
Erysimum cheiranthiodes, 104
Erysimum orientale, 103
Essex, **38**, 40
Euphorbia species, 115
Euphorbiaceæ, 115
Euphrasia officinalis, 112
Europe, seed from, 24, 27, 44, 63, 66
Evening Primrose, 107
Ewart, 11, 13
Excreta, mouse, 64
Experimental error, 72
Experiments, Danish, 75
Experiments, Van Helmont's, 19
Eyebright, 112

Factors, character, 2
Fan Barley, 80
Fanning dish, 29
Fat Hen, 12, 13, 113
Feeding-stuffs, cleanings as, 35
Female reproductive cell, 2, 3
Fen country, Ryegrass seed from, 37
Fenugreek, 99
Ferments, formation of, 8
Fertilization, 1, 3, 7
Fertilization, cross, 2
Fertilization, double, 8
Fertilization, Red Clover, 38
Fertilization, Self-, 2
Fescue, Chewing's, 45, **90**
Fescue, Fine-leaved Sheep's, **90**
Fescue, Hard, 90
Fescue, Meadow, 45, **89**, 90
Fescue Rat's-tail, 117
Fescue, Red, 90
Fescue, Reed, 90
Fescue, Sheep's, 90

Fescue, Tall, 90
Fescues, large, 89
Fescues, small, 90
Fescues, small, home-grown seed, 38
Festuca arundinacea, 90
Festuca elatior, 89, 90
Festuca ovina, 90
Festuca (ovina) durinscula, 90
Festuca (ovina) tenuifolia, 90
Festuca pratensis, 89, 90
Festuca rubra fallax, 45, 90
Festuca rubra genuina, 90
Festuca sciuroides, 117
Filter paper, 70
Finlayson test, 83
Finnish Foxtail, 45
Fiorin, 45, 94
Flail, threshing by, 30
Flanders Poppy, 13
Flannel, 70
Flax, 42, 61, 65, 75, 100
Flax cleaning, 30
Flax Dodder, 111
Flax, False, 103
Flax, False, Small-seeded, 103
Flax, seed supply, United Kingdom, 42
Flotation, 31
Fog, Yorkshire, 35, 49, 64, 96, 116
Fool's Parsley, 107
Forget-me-not, 111
Forget-me-not family, 111
Form groups, 101
Formates, 73
Formation of seed, 1
Fowl, digestion in, 12
Foxglove family, 112
Foxtail, Black, 116
Foxtail, Green, 92, 116
Foxtail, Knee'd, 92, 116
Foxtail Meadow, 21, 22, 45, 57, 91
Foxtail, Slender, 82, 92, 116
France, Import Regulations, 50
France, Red Clover seed supply, 38, 44
France, Ryegrass, 45, 66
French Beans, Dwarf, 99
French Red Clover, 67
Frosted seed, 69
Fumaria officinalis, 103
Fumariaceæ, 103
Fumitory, Common, 103
Fungi, 8, 51, 63, 64
Fungi, saprophytic, 65
Fungoid contamination, 68
Fungoid diseases, 63

Galeopsis Ladanum, 113
Galeopsis Tetrahit, 113
Galium aparine, 82, 108
Galium mollugo, 108
Galium verum, 108
Gall midge, 57
Gentians, 10
Gentner test of Ryegrasses, 87
Geraniaceæ, 105
Geranium, 49
Geranium dissectum, 67, 105
Geranium molle, 67, 96, 105
Geranium pusillum, 105
Germinability, criterion of, 54
Germinating ripeness, 8, 9, 10
Germination, 10, 16, 17, 23, 53, 73
Germination, artificial aids to, 72
Germination, delayed, 18, 69, 73
Germination energy, 69, 73, 75
Germination, hard seed, 14, 15
Germination, light in, 68–69
Germination, oxygen in, 68
Germination test, 53, 67, 71
Germinators, 21, 70, 71, 72
Germinators, cabinet, 70
Germinators, Jacobsen, 70
Germinators, refrigerator, 71
Germinators, Rodewald, 70
Gibberella Saubinetii, 65
Giglioli, 11
Gilgowan, 108
Glycine soja, 100
Goldthorpe Barley, 80
Grains, aleurone, 79
Grains, broken, 54, 55
Grains, cracked, 54, 55
Gramineæ, 86, 115
Grass, Black, 92
Grass, Crab, 115
Grass, Creeping Soft, 116
Grass family, 115
Grass seed, 9, 20, 24, 25, 29, 34, 36, 53, 59, 61, 72
Grass seed, shipping of, 24
Grasses, 7, 17, 21, 35, 37, 44, 55, 57, 61, 62, 64, 66, 67, 75, 86
Grasses, natural, 45
Grasses, permanent, 39
Grasses, wild, 64
Green Foxtail, 116
Grid sampling, 59
Gromwell, 111
Groundsel, 109
Growth, 2, 3, 16, 17, 19
Guarantee, 69

Hairgrass, Silvery, 116
Hairgrass, Wavy, 116
Hairy Vetch, 82
Hampshire, 39, 41
Hand harvesting, 22
Hand sieve, 27
Haploid number, 3
Hard Fescue, 90
Hard seed, 14, 15, 20, 72, 74
Hard seed, scarification of, 14
Hare's Ear, 108
Hare's Ear Mustard, 104
Harvester and thresher, combined, 22

Harvesting Red Clover, 39
Harvesting Wild White Clover, 39
Hawkweed, Ox-tongue, 109
Heartsease, 104
Hellbo test of Ryegrass, 50, 87
Helminthia, 109
Helminthosporium, 65
Hemlock, 107
Hemp Nettles, 113
Hen, Fat, 12, 13, 113
Holcus, 49, 96
Holcus lanatus, 35, 116
Holcus mollis, 116
Hollyhock family, 105
Home-grown seed supply, 36
Hordeum sativum, 79
Hordeum vulgare, 79
Hordeum zeocriton, 80
Horse, digestion in, 12
Horse-radish, 84
Humidity of atmosphere, absolute, 24
Humidity of atmosphere, relative, 24
Hybrid, 2, 42
Hypochæris radicata, 109
Hypogeal behaviour, 7

Immature kernels, 53, 55
Immortality, 1
Import Regulations, 35, 48
Impurity, 27, 30, 31, 32, 33, 34, 35, 49, 51, 52, **59**, 60, 66, 73, 76, 96, 97
Incubators, 70
Indian Corn, 81
Indigenous strains of Clover, 43
Indigenous strains of Cocksfoot, 43, 89
Indigenous strains of Ryegrass, 43, 87
Inert matter, **53**, 54, 55, 61, 76
Injurious weeds, 35, 49, **122**, 126
Injury to radicle tips, 54
Insect damage, 55, 56
Insect larvæ, 56, 57
Insect parasites, 57
Insects, predatory, 75
Instruments, sampling, 58
International conventions, 47
International Rules, 15, 54, 58
International Seed-Testing Association, **15**, 48, 54
International Seed-Testing Association certificate, 48
International Seed-Testing Association Rules, 50, 77
International traffic in seeds, 51
Interpretation of results, **73**, 74
Ireland, 37, 43
Ireland, Northern, noxious species, 50
Irish Free State, seed from, 37
Irish method of testing, 54
Irish Weeds and Agricultural Seeds Act, 1909, 50
Italian Red Clover, 66, 67
Italian Ryegrass, 37, 45, 48, 66, 73, **87**

Jacobsen germinator, 70
Jarowization, 19
Juncaceæ, 115
Juncus species, 115

Kent, Wild White Clover from, **39**, 40
Kentucky Bluegrass, 50, **92**
Kernels, immature, 53, **55**
Kernels, undeveloped, 53, **56**
Kidney Beans, 99
Kidney Vetch, 41, **99**
Kiln-drying, 9, 25
Knapweed, 110
Knee'd Foxtail, **92**, 116
Knotgrass, 82, 114

Labiatæ, 112
Laboratory sampling, 58
Lactuca sativa, 101
Lapsana communis, 110
Larkspur, Wild, 102
Late-flowering Red Clover, 94
Lathyrus odoratus, 99
Lathyrus pratensis, 106
Latitude in tests, 76
Leaf-stripe disease, 65
Leek, 86
Legumes, 14, 22, 54, 55, 72, 74, **94**, 100
Legumes, calcicole, 98
Leguminosæ, 11, 105
Leguminous crops, 94
Lens esculenta, 99
Lentil, 99
Lepidium campestre, 103
Lepidium sativum, 84
Lettuce, 101
Licence of Exemption from statutory requirements, 123, 130
Licensed Seed-Testing Stations, 121
Light in germination, 68, 69
Liliaceæ, 86
Linaria Elatine, 112
Linaria spuria, 112
Linum usitatissimum, 100
Linseed, 100
Lithospermum arvense, 111
Locust Beans, 99
Loganberry, 2
Lolium, 86
Lolium species and varieties, **86**, 88
Lolium temulentum, 65, 88, 116
Longevity, 11, 13
Loosestrife family, 107
Loosestrife, Hyssop-leaved, 107
Lotus, 96
Lotus corniculatus, 100
Lotus, Sacred, 13
Lucerne, 14, 15, 41, 74, **98**
Lychnis diurna, 104
Lychnis Githago, 104
Lychnis vespertina (alba), 67, 104
Lysenko, 19

Lythraceæ, 107
Lythrum hyssopifolium, 107

Macaroni Wheat, 79
Machinery, mixing, 58
Machinery, seed-cleaning, **27**, 34, 58
Madder family, 67, 108
Madder, Field, 108
Maize, 81
Male reproductive cell, **2**, 3
Mallow, 105
Malting Barleys, 80
Malva species, 105
Malvaceæ, 105
Manchukuo peat-beds, 13
Mangold, 17, 42, 64, 68, 71, **85**
Mangold-wurzel, 85
Manure heaps, **12**, 13
Matricaria inodora, 12, 109
Maturity, 55
Mayweed, 12
Mayweed, Scentless, 109
Mayweed, Stinking, 109
Meadow Fescue, 45, 52, 87, **89**, 90
Meadow Foxtail, 21, 22, 45, 57, **91**
Meadow Grass, Annual, 92
Meadow Grass, Rough-stalked, 38, 45, 92
Meadow Grass, Wood, 93
Meadow Grasses, 69, **92**
Medicago lupulina, 98
Medicago sativa, 98
Medicago species, 15, 98
Medicks, 15, 98
Melilot, 50
Melilotus alba, 50, 105
Melilotus officinalis, 105
Mice, damage by, 55, **56**
Micropyle, 17
Midge, gall, 57
Midlands, 41
Mignonette family, 104
Mignonette, Wild, 104
Miscellaneous Crops, 100
Mites, 56
Moisture, estimation of, **62**, 63
Moisture in germination, 68
Moisture in seed, 8, 9, **23**, 73, 74
Molinia cærulea, 117
Monkey-nut, 99
Monocotyledons, **5**, 7, 10, 67
Moor Grass, Purple, 117
Mould, 8, **65**, 69, 71
Mountain pasture, renovation of, 34
Mouse-eared Chickweed, 105
Mouse excreta, 64
Mucor, 65
" Mummy " Wheat, 13
Mustard, 41, 84
Mustard, Ball, 103
Mustard, Black, **84**, 103
Mustard, Brown, 83
Mustard, Hare's Ear, 103
Mustard, Treacle, 104
Mustard, White, 84
Mustard, Worm Seed, 103
Myosotis arvensis, 111

" Naked " Barley, 80
Naked Oats, 81
" Natural " Grasses, 45
Nelumbium speciosum, 13
Nemophila, 1, 69
Nepeta Cataria, 112
Neslia paniculata, 103
Nettle family, 115
Nettle, Hemp, 113
Nettle, Stinging, 115
New Zealand Brown Top, 45, 94
New Zealand Clover, 44
New Zealand Cocksfoot, 45
New Zealand Crested Dogstail, 45
New Zealand Fescue, 45, 90
New Zealand Ryegrass, 44
Nipplewort, 110
Nitrates (for germination), 73
Nobbe, Dr., 15
Nodule, root, 41
Northern Ireland Ryegrass seed, 37
Noxious weeds, 49, 50
Nucleus, **2**, 8
Nucleus, primary endosperm, 8

Oatgrass, 72, **91**
Oatgrass, Golden, 91
Oatgrass, Tall, 91
Oatgrass, Yellow, 91
Oats, 9, 63, 65, 73, **80**
Oats, Black Winter, 9, **18**
Oats, Black Winter, after-ripening of, 9
Oats, Bristle-pointed, 82
Oats, Common, 80
Oats, Naked, 81
Oats, Spring, after-ripening of, 9
Oats, Tartarian, 80
Oats, Wild, 82
Œnothera biennis, 107
Ohga, Dr., 13
Old Pasture Wild White Clover, 51, 96
Oligotrophus, 57
Onagraceæ, 107
Once-grown Wild White Clover, 51, 97
Onion, 7, 65, 67, **86**
Onobrychis sativa, 99
Oraches, 82, 114
Orobanchaceæ, 112
Orobanche minor, 112
" Other useful " species, 52
" Other weeds," 50
Ovary, **1**, 7
" Over-yeared " seed, 11
Ovule, 1
Ox-eye Daisy, 108
Ox-tongue, 109
Oxygen, 10, **16**, 68, 69.

Pacific Coast, shipment to, 24
Panama (route), 24
Panicum Crus-galli, 115
Panicum sanguinale, 115
Papaver dubium, 102
Papaver Rhœas, 102
Paper, filter, 70
Paper pads, blotting, 70
Parasites, insect, 57
Parasitic fungi, 51
Parasitic infection, 65
Parasitic weeds, 76
Parsley, 85
Parsley, Fool's, 107
Parsnip, 11, 18, 22, **85**
Pastinaca sativa, 85
Pasture, Mountain, renovation of, 34
Pasture, Old, Wild White Clover, 40, 96
Pea family, 11, 105
Peas, 7, 14, 18, 33, 55, 56, 64, 99
Peas, cleaning of, 30, 33
Peas, Garden, 18, 99
Peas, Field, 99
Peas, Sweet, 99
Penicillium, 65
Pennycress, 104
Peppercorn, 8
Perisperm, 8
Permanent Grasses, 39
Peterson, Dorph, 11, 12
Petri dishes, 70
Phalaris nodosa, 51
Phaseolus, 99
Phleum pratense, 89
Phoma, 64
Physiological development, 19
Picris echioides, 109
Picris hieracioides, 109
Pig, digestion in, 12
Pigweed, 113
Pimpernel, Scarlet, 150
Pisum arvense, 99
Pisum sativum, 99
Plantagineæ, 113
Plantago aristata, 113
Plantago lanceolata, 12, 29, 67, 113
Plantago major, 113
Plantago Rugelli, 113
Plantain, Bracted, 113
Plantain, Broad, 113
Plantain family, 113
Plantain, Rugel's, 113
Plumular bud, 67
Plumule, 7, 54, 55, 68
Poa, 96
Poa annua, 92
Poa compressa, 92
Poa, diagnosis of, 93
Poa nemoralis, 1, 93
Poa pratensis, 45, 50, **92**, 93
Poa, Rough-Stalked, 45, 50, 52, **92**
Poa, Smooth-Stalked, 45, 50, 52, **92**
Poa species, 69, 73, **92**, 96
Poa trivialis, 45, 50, **92**, 93
Poisoning in pigs, 65
Poland, clover seed from, 44
Polariscope test, Finlayson's, 83
Pollen grain, 1, 8
Pollination of Red Clover, 38
Polycotyledons, 5
Polygonaceæ, 114
Polygonum aviculare, 82, 114
Polygonum Convolvulus, 82, 85, 114
Polygonum Hydropiper, 115
Polygonum Persicaria, 82, 115
Poppy, Common Red, 102
Poppy, Flanders, 13
Poppy, Long Smooth-headed, 102
Porous porcelain dishes, 70
Potassium nitrate, 73
Potentilla monspeliensis, 107
Poterium, 50
Poterium muricatum, 106
Poterium sangiusorba, 106
Poultry meals, 35
Predatory insects, 75
Pre-soaking, 68
Price comparison, 74
Primary roots, 5
Primrose, Evening, 107
Primrose family, 111
Primrose species, 10
Primulaceæ, 111
Prohibited species, Canada, 50, 85
Prohibited species, United States, 50
Proportion of weed seeds, 67
Protoplasm, 1, 17
Protoplasmic molecule, 10
Provenance, 65
Prunella vulgaris, 67, 96, 112
Pulse crops, 99
Pure germinating seed, 15, **74**
Pure seed, 27, 49, 54, **59**, 71, 73, 76
Purity analysis, 29, **54**
Purity test, 48
Purity test technique, 57
Purple Moor Grass, 117

Rachilla, 56
Rachilla of Barley, 80
Rachilla of Fescue, 89
Rachilla of Ryegrass, 87
Radicle, 7, 54
Radicle, injury to, 54
Radicle-tip, damage to, 54
Radish, 84
Radish, Wild, 82, 103
Ragweed, American, 51, 110
Ragwort, 50, 109
Rain water, 68
Ranunculaceæ, 102
Ranunculus acris, 102
Ranunculus arvensis, 102
Ranunculus repens, 102

Ranunculus sceleratus, 102
Rape, 2, 42, 83, 84
Rape-kale crosses, 84
Raphanus Raphanistrum, 82, 103
Raphanus sativus, 84
Raspberry, 2
Real value, 15, 74
Red Bartsia, 112
Redshank, 82, 115
Redtop, 45, 94
Reduction division, 3
Refrigerator ship, 25
Refrigerators, 71
Regulation (Seed), English, 35, 50, 97, 125, 128
Regulation, staining of seed, 36
Renovation of mountain pasture, 34
Report, standard analysis, 52
Reproduction, 1
Reproduction cell, 2, 3
Reseda lutea, 104
Resedaceæ, 104
Respiration, 8, 16
Results, interpretation of, 73
Rhinanthus Crista-galli, 112
Rib cylinder machine, 29
Ribgrass, 12, 29, 67, 113
Ripeness, germinating, 8, 10
Ripening, 8, 9, 14, 16, 20, 21
Ripening, After-, 9, 10, 16, 18
Ripening in clovers, 21
Rodewald incubators, 70
Root-cap, 7
Root crops, 41, 83
Root nodule, 41
Root, seed supply, 41
Root system, 5, 55
Roots, branch, 54
Roots, lateral, 55
Roots, primary, 5, 55
Roots, secondary, 55
Rosa pratincola, 107
Rosaceæ, 106
Rose family, 106
Rose, Prairie, 107
Rothamsted, 12
Rough Chervils, 107
Rough-stalked Meadow Grass, 45, 92
Rubiaceæ, 108
Rules, International, 15, 50, 58, 77
Rumex, 49
Rumex Acetosa, 114
Rumex Acetosella, 114
Rumex crispus, 82, 114
Rumex obtusifolius, 114
Rush family, 115
Rushes, 115
Russian Thistle, 114
Rust disease of Celery, 64, 85
Rye, 63, 81
Ryegrass, 35, 36, 37, 52, 53, 60, 64, 69, 75, 76, 86, 96
Ryegrass, Argentine, 44, 88
Ryegrass, Chilean, 44, 91
Ryegrass, Gentner test, 87
Ryegrass, Hellbo test, 50, 87
Ryegrass, indigenous strains, 43
Ryegrass, Italian, 37, 45, 48, 66, 73, 76, 86, 87
Ryegrass, New Zealand, 66
Ryegrass, North American domestic, 44
Ryegrass, Pacey's, 88
Ryegrass, Perennial, 37, 39, 44, 48, 50, 73, 87
Ryegrass seed supply, 36, 44
Ryegrass, Sparse Flowered, 88

Sacred Lotus, 13
Sages, 112
Sainfoin, 22, 41, 50, 99
Salsify, 101
Salsola Kali, 114
Salvia, 112
Sample, analytical, 58, 59, 61
Sample, bulk, 57, 58
Sample, control, 72, 122
Sample, warehouse, 58
Sampling, 57, 129
Sampling, bulk, 57
Sampling grid, 59
Sampling instruments, 58
Sampling, laboratory, 58
Sampling, warehouse, 57
Sand, 70
Saponaria Vaccaria, 104
Saprophytic fungi, 65
Scarification, 21
Scarlet Pimpernel, 111
Scarlet Runners, 99
Scentless Mayweed, 109
Scirpus species, 115
Sclerotia, 51, 63, 64
Sclerotinia trifoliorum, 51, 64
Scotland, seed from, 37, 89
Scrophularineæ, 112
Scutellum, 79
Secale cereale, 81
Sedge family, 115
Sedges, 115
Seed Potatoes, Regulations in respect of, 131
Seed Testing, 46
Seed-Testing Association, European, 48
Seed-Testing Association, International, 15, 48
Seed-Testing conventions, 48
Seed-Testing, international standardization, 48
Seed-Testing, purpose of, 46
Seed-Testing Stations, 121, 137
Seed-Testing Stations, licensed, 121
Seed-Testing technique, 48
Seedling Blight, 65
Seedlings, broken, 55, 72

Seedlings, diseased, 72
Seedlings, healthy, 54, 67, 72
Seeds Act, 118, 120
Seeds Act, Adulteration of, 1869 (and 1878), 157
Seeds Act, 1909, Irish Weeds and Agricultural, 50, 119
Seeds (Amendment) Act, 1925, 131
Seeds (Amendment) Regulations, 1935, 131
Seeds Order (1917 and 1918), English Testing of, 49
Seeds Regulations, 1922, 120, 125
Self-fertilization, 2
Self-heal, 67, 96, 112
Senecio Jacobæa, 109
Senecio vulgaris, 109
Senescence, 11
Senility, 11
Septoria apii, 64
Setaria glauca, 116
Setaria viridis, 116
Shamrock, 97
Sheep's Fescue, 90
Sheep's Sorrel, 12, 13, 114
Shepherd's Purse, 104
Sherardia arvensis, 67, 108
Ship, refrigerator, 25
Shipping of seed, 24, 27
Sieve, 27, 30, 34, 71
Silene inflata, 104
Silvery Hairgrass, 116
Single-cut Cowgrass, 94
Slender Foxtail, 92
Small Fescues, 90
Smooth Crepis, 110
Smooth-stalked Poa, 92
Smut, 63
Soda, 73
Soft Grass, Creeping, 116
Soil, 12, 15, 18, 39, 54
Sonchus arvensis, 110
Sonchus asper, 110
Sonchus oleraceus, 110
Sorghum, 86
Sorrels, Common, 49, 114
Sorrels, 13
Sorrels, Sheep's, 12, 114
South America, 44, 66
South Europe, 44, 66
Sowthistle, Common, 110
Sowthistle, Creeping, 110
Sowthistle, Prickly, 110
Spear Plume Thistle, 110
Specific gravity, 27, 29, 31
Specularia species, 111
Speedwells, 112
Spergula arvensis, 105
Spinach, 85
Spinacia oleracea, 85
Spores, 32, 63, 64
Spot disease, 64
Sprat Barley, 80
Sprouting of grain, 82
Spurge, 115
Spurge family, 115
Spurrey, 105
Steamships, 25
Stellaria media, 105
Stinging Nettle, 115
Stinking Mayweed, 109
Stirlingshire, Seed from, 37
Storage, apple, 23
Storage, cold, 19
Storage conditions, 11
Storage in gases, 13
Storage in paper bags, 23
Storage in sacks, 24
Storage in vacuum, 13
Storage, seed, 23
Storage, starch, 7
Storage tissue, 7
Storage, ventilation in, 23
Straw, ripening of, 21
Strawberry Clover, 98
Strickland, 11
Subterranean Clover, 98
Suckling Clover, 50, 97, 128
Suction force, 67
Suffolk, 40
Sugar Beet, 85
Sugar Cane, 86
Sulphur Clover, 98
Sussex, 40
Swede Turnips, 41, 83
Sweden, seed from, 66
Sweet Pea, 99
Sweet Vernal, 91, 96

Tartarian Oats, 80
Technique of germination test, 71
Technique of purity test, 57
Technique of seed testing, 48
Temperature, 9, 17, 18, 19, 22, 23, 24, 25, 68, 70
Temperature, alternating, 69
Temperature, fluctuating, 18, 23
Teucrium species, 113
Test, chloral hydrate, 83 103
Test, " Continental," 54
Test, cyanophoric, 97
Test, Finlayson's polariscope, 83
Test, Gentner, 87
Test, Hellbo, 50, 87
Test, Irish, 54
Testa, 7, 14, 55, 63
Theophrastus, 11
Thistle, Creeping, 110
Thistle, Russian, 114
Thistle, Spear Plume, 110
Thistles, 50
Thlaspi arvense, 104
Thresher, 22, 27, 30
Tilletia caries, 63

Timothy, 37, 44, 45, 58, 60, 66, 89, 92
Timothy, indigenous, 43
Toadflax, Pointed, 112
Toadflax, Round-leaved, 112
Trade tests, 46, 47
Tragopogon porrifolius, 101
Transport of seed, 24, 62
Trefoil, 14, 22, 41, 98
Trefoil, seed supply, 41
Trifolium, 94
Trifolium angulatum, 128
Trifolium dubium, 50, 97, 128
Trifolium filiforme, 97
Trifolium fragiferum, 98
Trifolium glomeratum, 106, 128
Trifolium hybridum, 95
Trifolium incarnatum, 97
Trifolium medium, 98
Trifolium ochroleucum, 98
Trifolium parviflorum, 128
Trifolium procumbens, 97, 106, 128
Trifolium repens, 96
Trifolium subterraneum, 98
Triticum vulgare, 79
Tropics, transport of seed in, 24
Turnip, 2, 20, 35, 41, 52, 55, 75, 83
Turnip, seed supply, 41
Turnip, Swede, 41, 83
Tylenchus, 57

Umbelliferæ, 84, 101, 107
Undeveloped kernels, 53
United Kingdom seed supplies, 36
United Kingdom, trading within, 15
United States of America, 36, 44
United States of America, prohibited species, 50
Urtica dioica, 115
Urticaceæ, 115
" Useful " impurities, 52
" Useful " seed, 74
Ustilago, 63

Value, real, 74
Van Helmont, 19
Variation fortuitous, 72
Variation in tests, 77
Vascular system, 5
Ventilation in storage, 22, 23
Vermin, damage by, 55, 56
Vernal, Sweet, 91, 96
Vernalization, 18, 19, 42
Vicia hirsuta, 82
Viability, 24, 56
Viability, of weed seeds, 12
Vitality of " Mummy " Wheat, 13
Vitriol soaking, 13

Wales, 43
Wallflowers, 83
Warehouse sampling, 57, 60
Wart Disease of Potatoes Order, 1923, 131
Water, 9, 15, 16, 17, 37, 68, 69, 70, 71
Water Pepper, 115
Water vapour, 54
Watercress, 84
Wavy Hairgrass, 116
Weed seeds, 32, 34, 49, 61, 73, 76, 101, 102
Weed seeds, germinability of, 52
Weed seed, viability of, 12
Weeds of Cereals, 82
Weeds of Wild White Clover, 96
Weeds, compulsory destruction of, in Northern Ireland, 50
Weeds, diagnostic, 51, 67, 96, 97
Weeds, distribution in manure, 12
Weeds, injurious, 35, 49
Weeds, noxious, 50
Weeds, " other," 50, 51
Weeds, parasitic, 76
Weevilled Peas, 56
Weevils, 33, 56
Weighing of samples, 61
Weight, " absolute," 61
Weight, bushel, 61, 73
Wheat, 7, 13, 36, 52, 57, 63, 79
Wheat, Bread, 79
Wheat, bunt in, 32, 63
Wheat grain, 5, 32
Wheat grain from tombs, 10, 13
Wheat, limits of latitude, 19
Wheat, Longevity of, 13
Wheat, Macaroni, 79
Wheat, Russian Winter, 19
White Clovers, 96
White Clovers, Dutch, 96
White Mustard, 84
Wick-strip, 70
Wild Carrot, 49, 67, 107
Wild grasses, 64
Wild Larkspur, 102
Wild Mignonette, 104
Wild Oats, 82
Wild Radish, 103
Wild White Clover, 96
Wild White Clover, diagnosis of, 96
Wild White Clover, " once grown," 97
Wild White Clover, " old pasture." 96
Willow Herb, 13
Willow Herb family, 107
Wind pollination, 2
Windblast machine, 29
Winnower, 30
Wisket, 30
Wood Meadow Grass, 93
Woodsages, 113
Wood Rush, Field, 96

Yarrow, 109
Yellow Rattle, 112
Yorkshire Fog, 35, 49, 64, 116

Zea mays, 81
Zig-zag Clover, 98
Zoroaster, 11
Zygote, 3

C. F. T. R. I. LIBRARY, MYSORE.

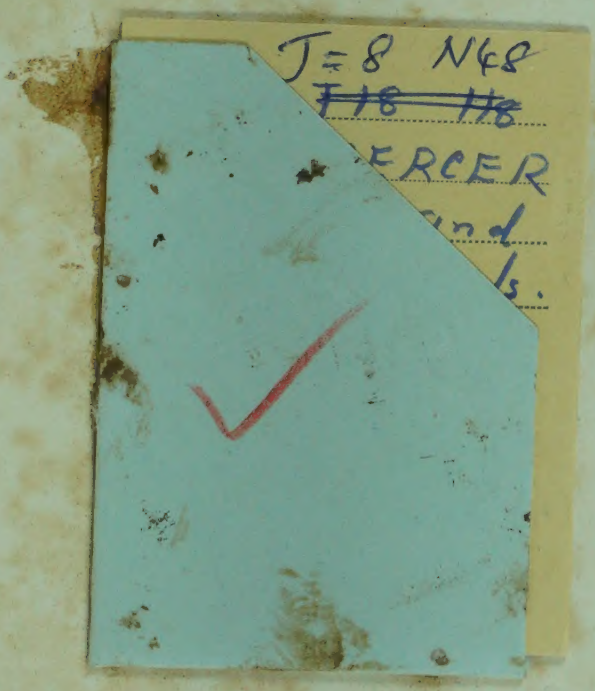
Acc. No. 886

Call No. ~~J18~~ J=8 ~~N58~~

Please return this publication on or before the last DUE DATE stamped below to avoid incurring overdue charges.

P. No.	Due date	Return date

CFTRI-MYSORE
886
Farm and garden


T=8 N48
T16 H8
ERCER
nd
ls.